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Carderock Division
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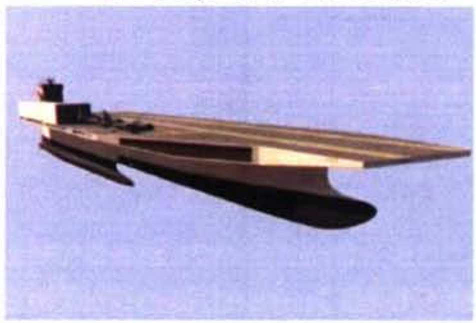
Hydromechanics Department Report

Bare Hull Resistance Experiments and LDV Wake Surveys for a Trimaran Concept of a Heavy Air Lift Seabasing Ship (HALSS) Represented by Model 5651

By
Daniel J. Lyons and
Christopher J. Chesnakas



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Bare hull resistance experiments were conducted for the HALSS trimaran, a Heavy Air Lift Seabasing Ship, as represented by Model 5651. During the first phase of testing, using just the HALSS center hull, two different bow sections, stem and bulbous bow, where tested. Further testing was completed with the HALSS center hull only, fitted with the best performing bow section and twin skegs, at two different drafts. The purpose of the second phase of testing was to investigate the resistance characteristics of the HALSS trimaran with a matrix of three longitudinal and three transverse side hull configurations.

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Also, further testing was completed to evaluate the resistance characteristics of three different center-hull-to-side-hull draft variations. These experiments were completed with HALSS center hull drafts of 11 meters and 12 meters and various shallower side hull drafts. Additionally, In order to design a propeller for this hull, the nominal wake at the starboard propeller plane was measured using Laser Doppler Velocimetry (LDV).

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NOTATION

The notation contained herein conforms with International Towing Tank Conference (ITTC) Symbols and Terminology List – 1993.

STANDARD SYMBOLS (Abbreviated List)

C_A	Ship/Model Correlation Allowance
C_F	Frictional Resistance Coefficient
CFD	Computational Fluid Dynamics
C_R	Residuary Resistance Coefficient
C_T	Total Resistance Coefficient
C_{Th}	Propeller Thrust-Loading Coefficient
C_V	Viscous Resistance Coefficient
C_W	Wavemaking Resistance Coefficient
D	Drag (in general)
F_D	Towing Force in self propulsion test
F_n	Froude Number
J	Propeller Advance Coefficient (Advance number)
J_V	Apparent (Ship Speed) Advance Coefficient
K_Q	Torque Coefficient
K_T	Thrust Coefficient
LBP	Ship Length between Perpendiculars
L_C	Chord Length (stern flap or transom wedge)
LWL	Ship Waterline Length
n	Propeller Rate of Revolution (r/sec)
P_D	Delivered Power at Propeller
P_E	Effective Power (Resistance)
Q	Torque
R	Resistance (in general)
R_n	Reynolds Number
RPM	Propeller Rate of Revolution (r/min)
S	Ship Wetted Surface
t	Thrust Deduction Fraction
T	Thrust
TE	Trailing Edge
V	Speed (Velocity)
V_A	Speed of Advance of Propeller
w_Q	Wake Fraction (torque identity)
w_T	Wake Fraction (thrust identity)
X	Longitudinal Distance
Y	Transverse Distance
Z	Vertical Distance
α	[Alpha] Angle (in general)
β	[Beta] Advance Angle of propeller blade
η	[Eta] Efficiency (in general)
κ	[Kapa] Kinematic Capillarity (ft^3/sec^2)
λ	[Lambda] Model linear scale ratio
μ	[Mu] Viscosity ($lb*sec/ft^2$)
ν	[Nu] Kinematic Viscosity (ft^2/sec)
ρ	[Rho] Water Density ($lb*sec^2/ft^4$)
σ	[Sigma] Surface Tension (lb/sec^2)

INTERNATIONAL SYSTEM OF UNITS (SI) CONVERSION FACTORS

U.S. CUSTOMARY	METRIC EQUIVALENT
1 inch	25.4 millimeter (mm), 0.0254 meter (m)
1 foot (ft)	0.3048 meter (m)
1 pound of force	0.4536 kilograms (kg)
1 foot - pound (ft. - lb.)	0.1382 kilogram - meter (kg - m)
1 foot per second (ft./s.)	0.3048 meter per second (m/s)
1 knot	0.5144 meter per second (m/s)
1 horsepower (HP)	0.7457 kilowatts (kW)
1 long ton	1.016 tonnes, 1.016 metric tons, or 1016.0 kilograms
1 inch water (60°F)	248.8 pascals (pa)

ABSTRACT

Bare hull resistance experiments were conducted for the HALSS trimaran, a Heavy Air Lift Seabasing Ship, as represented by Model 5651. During the first phase of testing, using just the HALSS center hull, two different bow sections, stem and bulbous bow, where tested. Further testing was completed with the HALSS center hull only, fitted with the best performing bow section and twin skegs, at two different drafts. The purpose of the second phase of testing was to investigate the resistance characteristics of the HALSS trimaran with a matrix of three longitudinal and three transverse side hull configurations. Also, further testing was completed to evaluate the resistance characteristics of three different center-hull-to-side-hull draft variations. These experiments were completed with HALSS center hull drafts of 11 meters and 12 meters and various shallower side hull drafts. Additionally, In order to design a propeller for this hull, the nominal wake at the starboard propeller plane was measured using Laser Doppler Velocimetry (LDV).

ADMINISTRATIVE INFORMATION

The work described in this report was performed at the David Taylor Model Basin, Carderock Division, Naval Surface Warfare Center (NSWCCD), herein referred to as DTMB, by the Resistance and Powering Division (Code 5200). The work was sponsored by the Office of Naval Research (ONR) under Work Unit Numbers 06-1-5200-192 and 07-1-5200-216.

INTRODUCTION

Code 5200 was asked to conduct bare hull and appended resistance experiments for a trimaran variant of HALSS, a conceptual design of a Heavy Air Lift Seabasing Ship. The concept of the HALSS is to provide support for military elements in seabasing, strategic mobility and focused logistics during the undertaking of expeditionary warfare missions. As conceived, the initial role of a HALSS ship will be to provide support as a high-speed platform for an early insertion of all aspects; personnel, equipment, supplies, and logistics of a military force deployment. A subsequent role for a HALSS ship, in its seabasing capacity, is as a versatile, mobile, high-speed platform in support of a multi-mission military force during an extended deployment in theater.

The HALSS trimaran design has various elements maximized to provide the necessary performance characteristics and capacities for it's wide range of mission requirements. One aspect of the HALSS trimaran is an 185,900 ft^2 flight deck to accommodate both fixed wing and rotary winged aircraft operations from an advanced seabase posture. The HALSS trimaran concept offers a large flight deck operations area, with a relatively long runway length suitable for the operations of C-130J and KC-130 fixed wing aircraft. The C-130J, *Hercules,* is a tactical cargo and personnel transport aircraft while the KC-130 variant is a multi-role, multi-mission tactical tanker/transport. Also, HALSS will be deployed with the CH-46, *Sea Knight*, a multi-mission, combat logistics support, vertical replenishment, search and rescue, special operations, cargo and troop transport helicopter. The relatively stable nature of the trimaran design, low roll and pitch motions in a seaway, is expected to offer the seakeeping and stability characteristics that are especially well suited for flight deck operations.

Also, the relative stability of the HALSS trimaran makes it an ideal design choice for another of the HALSS ship's function, which is as accommodations and mission support for up to 1700 troops. The HALSS trimaran concept has relatively large cargo and warehouse capacity to provide for the logistical support needs of extended troop deployments. The HALSS trimaran concept is designed to have top transit speed of 35 knots.

For the experiments reported herein, the speed range tested corresponds to 10 knots to 45 knots. For the first phase of testing, with the HALSS center hull only, two different bow sections, stem and bulbous bow, where tested. Further testing, with the HALSS center hull only fitted with the best performing bow section and twin skegs, at a displacement corresponding to both 11 meter and 12 meter drafts was completed.

The purpose of the second phase of testing was to investigate the resistance characteristics of the HALSS trimaran with a matrix of three longitudinal and three transverse side hull configurations. Also, further testing was completed to evaluate the resistance characteristics of three different center-hull to side-hull draft variations. These experiments were completed with HALSS center hull drafts of 11 meters and 12 meters and various shallower side hull drafts.

DESCRIPTION OF MODEL

Model 5651, made to a scale ratio (λ) of 54.0, represents the HALSS trimaran concept ship. Model 5651 was manufactured by the Advanced Marine Division of the Computer Sciences Corporation (CSC). Ship and model hull form characteristics for Model 5651 are presented in Figure 1.

Model 5651 consisted of three separate hulls, one center hull and two identical side hulls, connected together with aluminum cross structure pieces into a trimaran. The center hull was constructed to allow for the testing of two different bow sections. The removable bow sections, both wave piercing designs, were of a stem bow and bulbous bow types. Also, the center hull was fitted with twin removable skegs so that the bare hull resistance of the center hull could be experimentally determined.

The two smaller side hulls were attached to the center hull, to form the trimaran configurations, using two rigid aluminum extrusions as cross members attached with manufactured plates and brackets. To account for the three different longitudinal locations of the side hulls relative to the center hull, the mounting plates connecting the center hull to the aluminum cross members were repositioned as needed. Also, the brackets attaching the side hulls to the aluminum cross members could be loosened and relocated to allow for the side hull locations to be changed in the transverse direction. Finally, the relative vertical positions of the side hulls to the center hull were reconfigured using sets of Renwood blocks placed between the center hull and the cross structure mounting plates. Figure 2 presents a sketch of Model 5651 showing the relative locations of side hulls that were tested.

In order to induce turbulent flow over the length of the model hull, one-eighth inch diameter by one-tenth inch (0.254 cm) height turbulence stimulation studs were placed approximately 2 inches aft of the stem, the approximate location of the forward perpendicular, and spaced 1 inch apart. The center hull and side hulls of Model 5651 were lined with station and waterline markings. Drydock photographs of Model 5651, representing HALSS, are shown in Figure 3.

EXPERIMENTAL PROCEDURE

All phases of the test program for the HALSS ship, as represented by Model 5651, were conducted on Carriage 1 of the deep-water basins at DTMB. A summary is presented in Table 1 of the experimental agenda outlining all HALSS center hull to side hull variations tested with Model 5651. Hydrostatic calculations for each condition tested were provided by Dr. Igor Mizine, of the Advanced Marine Division of the Computer Sciences Corporation (CSC), and are presented here in Figure 1 and Table 2. The model ballasting was adjusted so as to represent each specific ship configuration and corresponding displacement.

For each experiment, the model was restrained in surge, sway, and yaw, but was free to pitch, heave, and roll. The model was tested at speeds corresponding to a full-scale speed range of 10 to 45 knots. Resistance was measured with a 50 pound capacity, 4 inch DTMB block gauge. A linear bearing, floating platform tow post system and grasshopper were utilized for attaching the model to the carriage. The tow post attaches a captive ship model under the floating girder of the towing carriage for the purpose of measuring longitudinal (drag) and transverse (sway) forces. This is accomplished with the use of two block gauges attached to the ship model by means of double axis gimbals which allows the standard model freedoms of motion. The entire force measurement system is able to move vertically to compensate for model sinkage or rise. This vertical compensation allows for the measurement of drag to remain precisely in the direction of movement, parallel with the water surface, and consistent with the method of gauge calibration. The adjustability of the towing system also allows for model side force to be not only measured, at the tow post attachment point, but also reduced to negligible levels, prior to the resistance tests. Any side force, due to the model not being perfectly aligned longitudinally or symmetrically, was measured at the tow post with a second 20 pound capacity 4 inch DTMB block gauge. If side force was detected, the model alignment was adjusted by changing the model to carriage attachment point nearest the stern (the grasshopper), until a side force measurement nominally no greater than 1% of drag force was attained.

Dynamic sinkage, defined as positive downward, was measured with two wire potentiometers, which were located at or near the forward and aft perpendiculars of the center hull. Vertical difference between the forward and aft measurement points was used for the calculation of running pitch angle, defined as positive bow up.

During the first phase of testing, using just the HALSS center hull, two different bow sections, stem and bulbous bow, where tested. Further testing was completed with the HALSS center hull only, fitted with the best performing bow section and twin skegs, at a displacement corresponding to both 11 meters and 12 meters drafts. The purpose of the second phase of testing was to investigate the resistance characteristics of the HALSS trimaran with a matrix of three longitudinal and three transverse side hull configurations. Also, further testing was completed to evaluate the resistance characteristics of three different center hull to side hull draft variations. These experiments were completed with HALSS center hull drafts of 11 meters and 12 meters and various shallower side hull drafts. Table 2 lists all ship/model test parameters for each experiment with the HALSS trimaran represented by Model 5651.

RESULTS AND CONCLUSIONS

Resistance data presented in this report are for the full-scale HALSS class vessel operating in smooth, deep salt water with uniform temperature of 59° F (15° C). A correlation allowance (C_A) equivalent to 0.00000 was selected in accordance with the guidelines set forth in the U.S. Navy Ship Power Margin Policy [1] and used in conjunction with the 1978 ITTC Model-Ship Correlation Line for all the frictional resistance calculations. Standard DTMB analysis methods, as outlined by Grant and Wilson [2], were employed in reducing the experimental data. All full scale predictions presented in this report do not include Still Air Drag or Power Margin Factor.

Photographs of Model 5651, center hull only, during testing at various speeds, representing HALSS at 11.5 m and 12.0 m drafts, are presented in Figure 4. Figure 5 shows Model 5651, with the center hull at the 11.5 m draft and various side hull configurations, being towed at various speeds. Full scale resistance predictions are presented in Figures 6 through 15 and Tables 3 through 15. The dynamic sinkage at the forward (FP) and aft (AP) perpendiculars, and resultant pitch angle were measured for each configuration tested and full scale predictions for the HALSS trimaran are reported herein in Figures 16 through 24 and Tables 16 through 24.

ACKNOWLEDGMENTS

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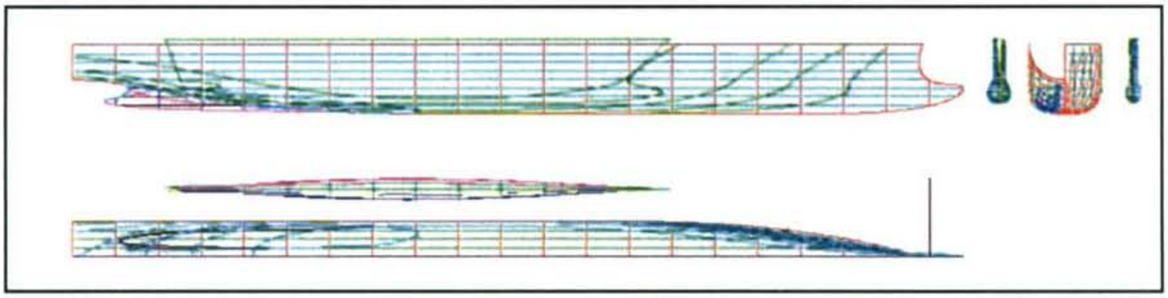
Trimaran Heavy Air Lift Seabasing Ship – HALSS (Model 5651)



NOTES:

1. Dimensions are given relative to coordinate system origin, except for M Trans and M Long which are given relative to the resultant waterplane.

2. CP is based on the wetted length (not nec. = LWL). All other coefficients are based on LWL and maximum draft above.

3. The accuracy of the sectional area curve, maximum section area and location, and prismatic and midship section coefficients are affected by the surface mesh density, and the number and location of defined stations. In addition, for trimmed waterplanes the sections are no longer exactly perpendicular to the waterplane, also affecting accuracy.

4. The displacement-length ratio is defined as the computed vessel displacement in long tons divided by the cube of one-hundredth of the waterline length in feet.

5. The moment to change trim is computed with the assumption that the center of gravity is at the flotation plane.

Figure 1. Ship and model hull form characteristics of the HALSS trimaran, represented by Model 5651.

Draft (m)	Weight (tonnes)	LCG (m)	TCG (m)	VCG (m)	LOA (m)
6.5	30,260,847.0	165.642	-1.08E-14	0	311.97
7.0	33,873,895.5	165.863	-8.54E-15	0	311.97
7.5	37,502,238.0	165.952	-7.11E-15	0	311.97
8.0	41,100,676.7	165.931	-1.42E-14	0	311.97
9.0	48,139,957.2	165.623	-1.65E-14	0	311.97
10.0	54,880,536.6	165.089	-5.33E-14	0	311.97
10.5	58,195,890.3	164.894	-2.12E-14	0	311.97
11.5	64,796,618.2	164.740	1.72E-13	0	311.97
12.0	68,119,620.3	164.774	1.96E-13	0	311.97
12.5	71,494,807.3	164.904	1.50E-13	0	311.97
13.0	74,914,635.3	165.078	1.77E-12	0	311.97
13.5	78,373,788.8	165.273	4.17E-11	0	311.97
14.0	81,866,795.4	165.477	1.95E-10	0	311.97
15.0	88,943,270.7	165.889	1.22E-09	0	311.97
17.5	107,071,007.0	166.812	1.17E-09	0	311.97
20.0	125,688,517.5	167.480	-2.89E-09	0	311.97

Draft (m)	LWL (m)	BOA (m)	BWL (m)	Depth (m)	Freeboard (m)	Volume (m^3)
6.5	292.67	54.86	54.58	26.50	20.0	29496.88
7.0	292.14	54.86	54.84	26.50	19.5	33018.71
7.5	292.26	54.86	54.71	26.50	19.0	36555.45
8.0	292.34	54.86	54.55	26.50	18.5	40063.04
9.0	292.51	54.86	53.99	26.50	17.5	46924.61
10.0	291.78	54.86	53.17	26.50	16.5	53495.02
10.5	289.76	54.86	52.68	26.50	16.0	56726.67
11.5	290.01	54.86	51.70	26.50	15.0	63160.75
12.0	300.01	54.86	51.27	26.50	14.5	66399.86
12.5	299.25	54.86	51.05	26.50	14.0	69689.84
13.0	298.72	54.86	51.05	26.50	13.5	73023.33
13.5	298.26	54.86	51.05	26.50	13.0	76395.15
14.0	297.89	54.86	51.05	26.50	12.5	79799.98
15.0	297.37	54.86	51.05	26.50	11.5	86697.80
17.5	296.76	54.86	51.06	26.50	9.0	104367.88
20.0	296.89	54.86	51.07	26.50	6.5	122515.37

Figure 1. Continued.

Draft (m)	LCB/LWL	LCB (m)	TCB (m)	VCB (m)	A0
6.5	0.600	165.642	-1.08E-14	4.020	196.168
7.0	0.604	165.863	-8.54E-15	4.312	215.287
7.5	0.606	165.952	-7.11E-15	4.596	235.373
8.0	0.607	165.931	-1.42E-14	4.872	254.686
9.0	0.607	165.623	-1.65E-14	5.403	292.771
10.0	0.603	165.089	-5.33E-14	5.905	329.441
10.5	0.595	164.894	-2.12E-14	6.153	347.075
11.5	0.572	164.740	1.72E-13	6.647	380.916
12.0	0.549	164.774	1.96E-13	6.896	397.292
12.5	0.549	164.904	1.50E-13	7.148	413.547
13.0	0.548	165.078	1.77E-12	7.404	429.810
13.5	0.548	165.273	4.17E-11	7.662	446.082
14.0	0.548	165.477	1.95E-10	7.922	462.360
15.0	0.549	165.889	1.22E-09	8.446	494.937
17.5	0.551	166.812	1.17E-09	9.768	576.471
20.0	0.554	167.480	-2.89E-09	11.100	658.117

Draft (m)	XA0	WetSurf (m^2)	D-L Ratio	Area WP	LCF
6.50	204.330	10571.380	33.64	6998.24	168.05
7.00	203.286	11311.799	37.86	7074.10	167.31
7.50	202.406	12037.074	41.87	7049.25	166.28
8.00	201.789	12757.386	45.85	6971.07	165.12
9.00	200.660	14161.393	53.61	6709.23	162.35
10.00	199.609	15499.794	61.57	6488.15	161.24
10.50	199.113	16154.877	66.67	6443.58	162.17
11.50	198.286	17466.595	74.04	6450.58	164.66
12.00	198.038	18159.006	70.31	6522.37	166.43
12.50	197.879	18850.512	74.36	6625.93	168.23
13.00	197.740	19501.012	78.33	6707.96	169.14
13.50	197.608	20141.842	82.32	6778.36	169.80
14.00	197.480	20777.683	86.31	6841.32	170.28
15.00	197.239	22042.482	94.27	6952.45	170.94
17.50	196.706	25196.246	114.18	7173.26	171.50
20.00	196.255	28364.391	133.86	7339.49	171.02

Figure 1. Continued.

Draft (m)	LCF/LWL	TCF	VCF	Cb	Cm
6.5	0.608	6.37E-15	6.50	0.284	0.553
7.0	0.609	3.02E-15	7.00	0.294	0.561
7.5	0.607	4.19E-15	7.50	0.305	0.574
8.0	0.605	-2.19E-15	8.00	0.314	0.584
9.0	0.596	-7.12E-15	9.00	0.330	0.603
10.0	0.590	3.92E-15	10.00	0.345	0.620
10.5	0.585	0.00E+00	10.50	0.354	0.627
11.5	0.572	5.64E-16	11.50	0.366	0.641
12.0	0.555	-3.90E-15	12.00	0.360	0.646
12.5	0.560	4.94E-15	12.50	0.365	0.648
13.0	0.562	5.42E-16	13.00	0.368	0.648
13.5	0.563	-2.68E-15	13.50	0.372	0.647
14.0	0.565	0.00E+00	14.00	0.375	0.647
15.0	0.566	4.19E-15	15.00	0.381	0.646
17.5	0.567	-5.07E-16	17.50	0.394	0.645
20.0	0.566	-2.48E-15	20.00	0.404	0.644

Draft (m)	Cwp	Cp	Cpaft	Cpfwd
6.5	0.438	0.503	0.549	0.493
7.0	0.442	0.512	0.571	0.497
7.5	0.441	0.518	0.583	0.499
8.0	0.437	0.524	0.591	0.503
9.0	0.425	0.533	0.604	0.510
10.0	0.418	0.540	0.610	0.516
10.5	0.422	0.543	0.614	0.519
11.5	0.430	0.551	0.622	0.525
12.0	0.424	0.536	0.563	0.528
12.5	0.434	0.540	0.569	0.531
13.0	0.440	0.545	0.576	0.534
13.5	0.445	0.549	0.582	0.537
14.0	0.450	0.553	0.589	0.539
15.0	0.458	0.561	0.601	0.544
17.5	0.473	0.580	0.629	0.555
20.0	0.484	0.597	0.652	0.565

Figure 1. Continued.

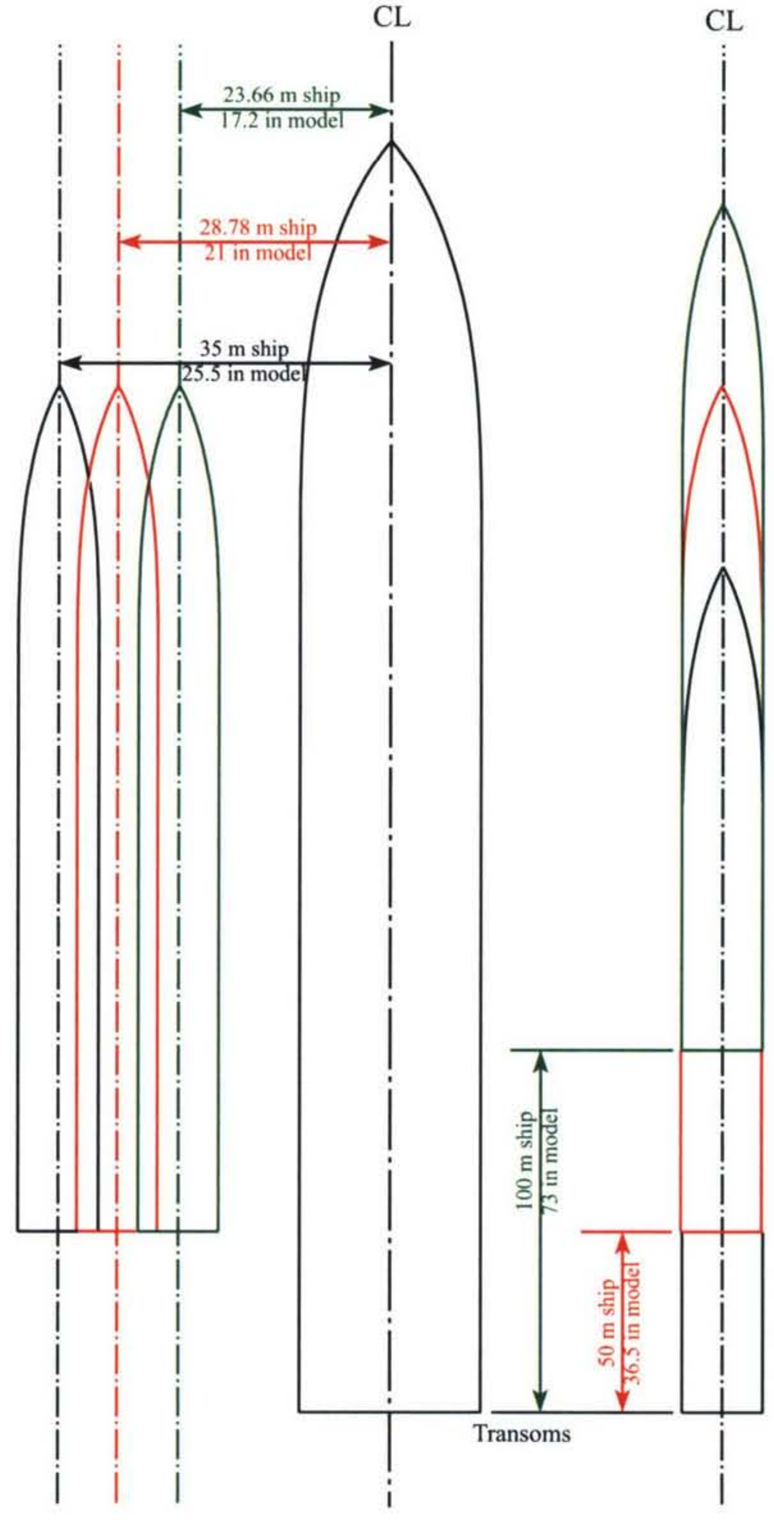


Figure 2. Sketch of Model 5651 showing relative locations of side hulls as tested.

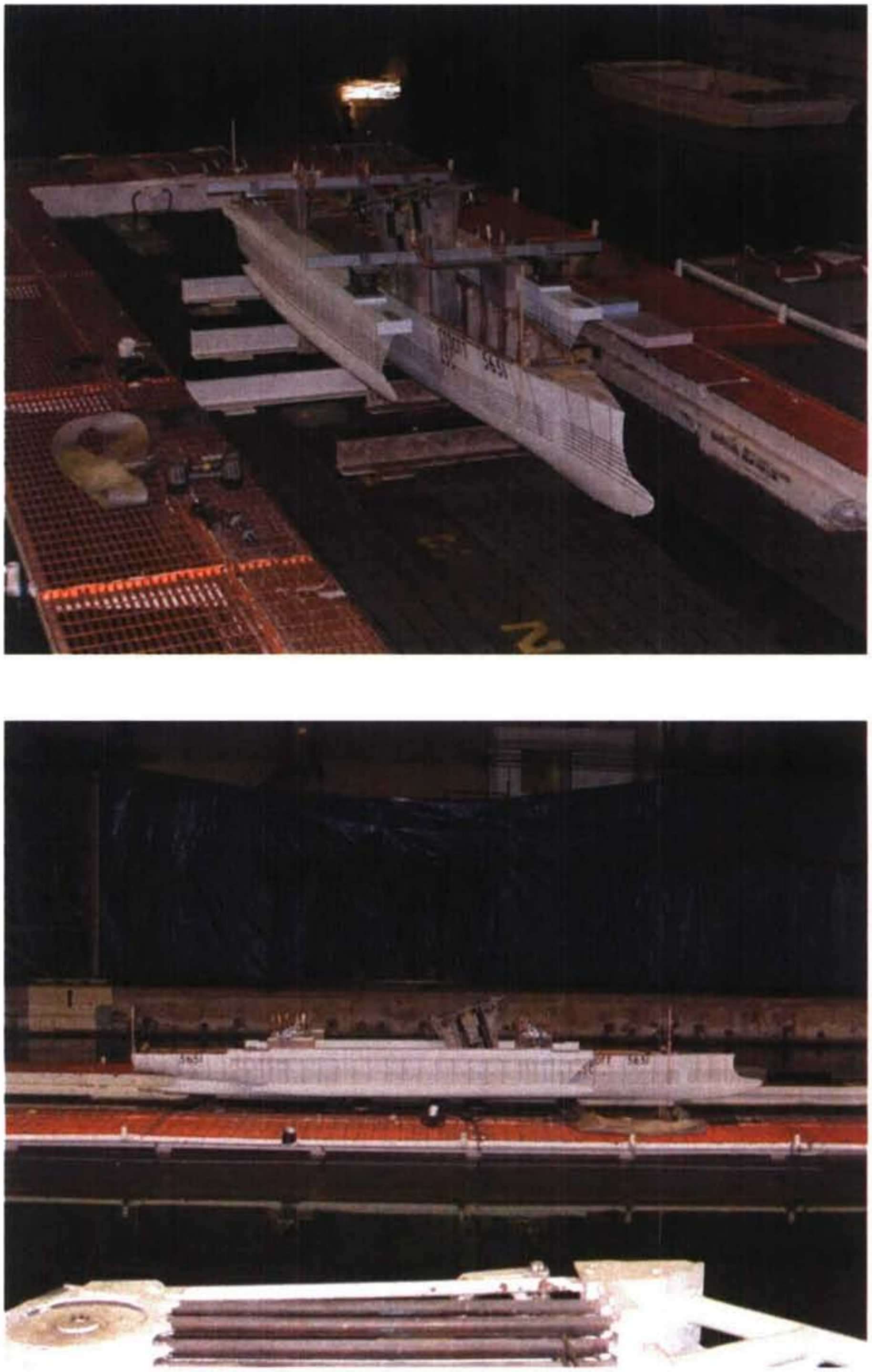


Figure 3. Drydock photographs of Model 5651, representing HALSS.

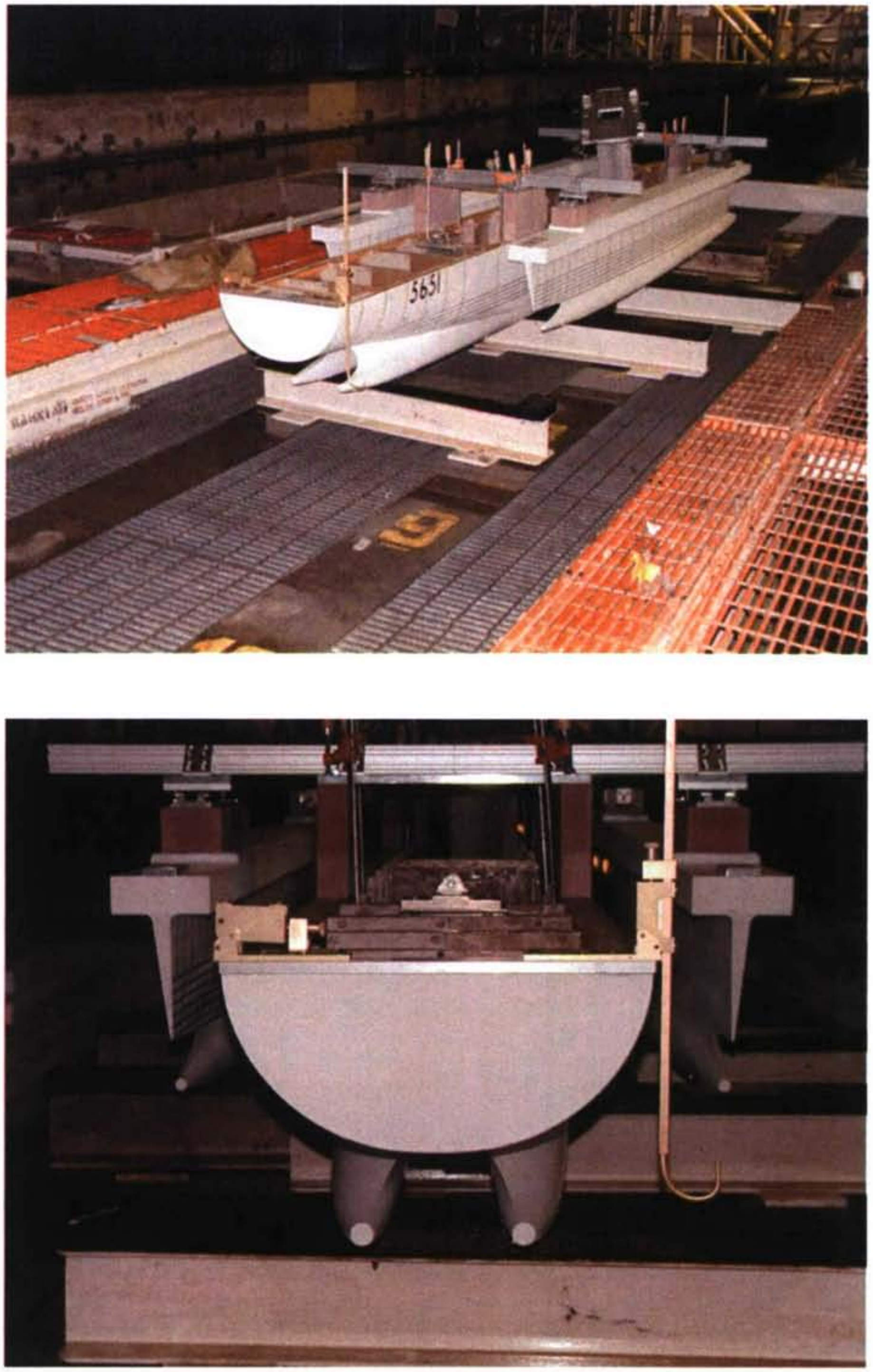


Figure 3. Continued.

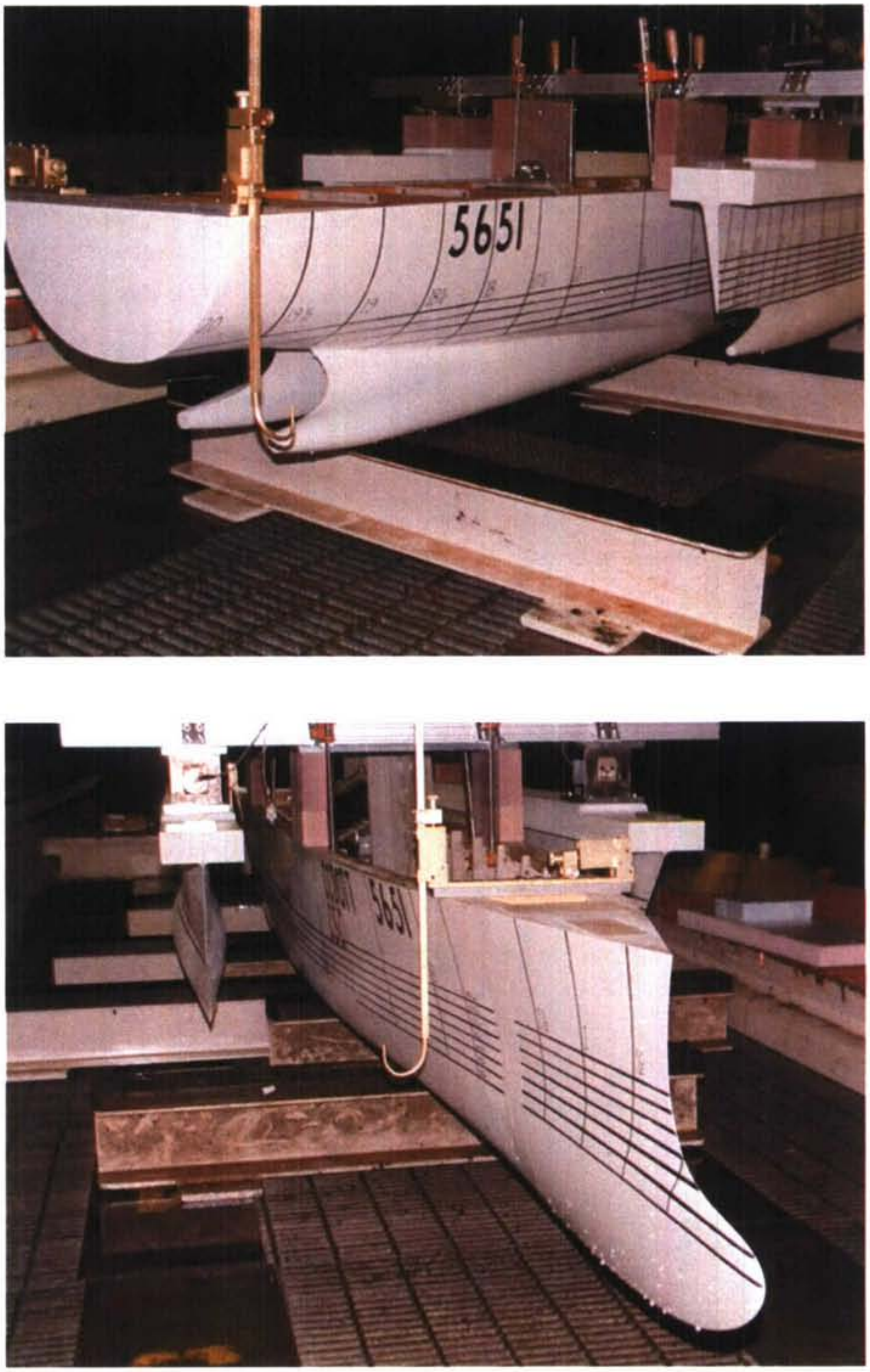


Figure 3. Continued.

Center Hull Only @ 11.5 m Draft - 30 Knots

Center Hull Only @ 12.0 m Draft - 30 Knots

Figure 4. Photographs of Model 5651, representing HALSS at 11.5 m and 12.0 m drafts, center hull only.

Center Hull Only @ 11.5 m Draft - 40 Knots

Center Hull Only @ 12.0 m Draft - 40 Knots

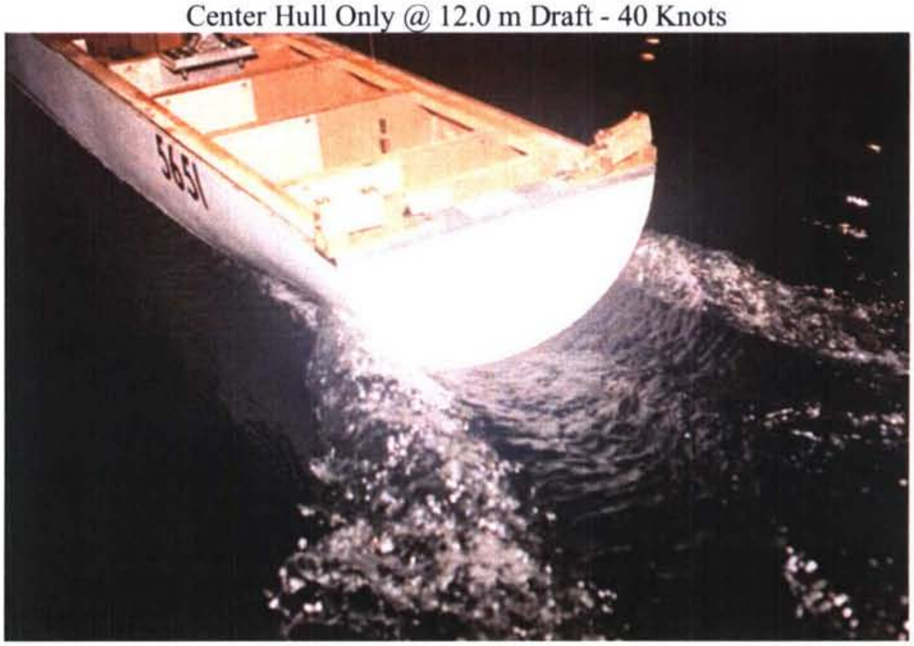


Figure 4. Continued.

Center Hull Only @ 11.5 m Draft - 45 Knots

Center Hull Only @ 12.0 m Draft - 45 Knots

Figure 4. Continued.

Center Hull @ 11.5 m Draft
Side Hulls in Middle Longitudinal & Inboard Transverse Location @ 7.5 m Drafts - 35 Knots

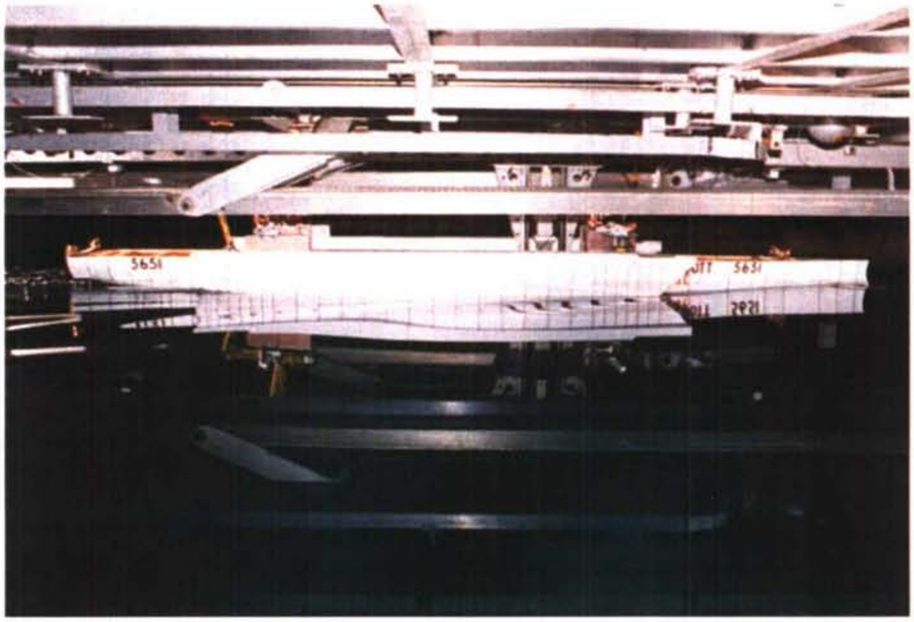


Figure 5. Photographs of Model 5651, representing HALSS at 11.5 m draft with various side hull configurations.

Center Hull @ 11.5 m Draft
Side Hulls in Middle Longitudinal & Inboard Transverse Location @ 7.5 m Drafts - 40 Knots

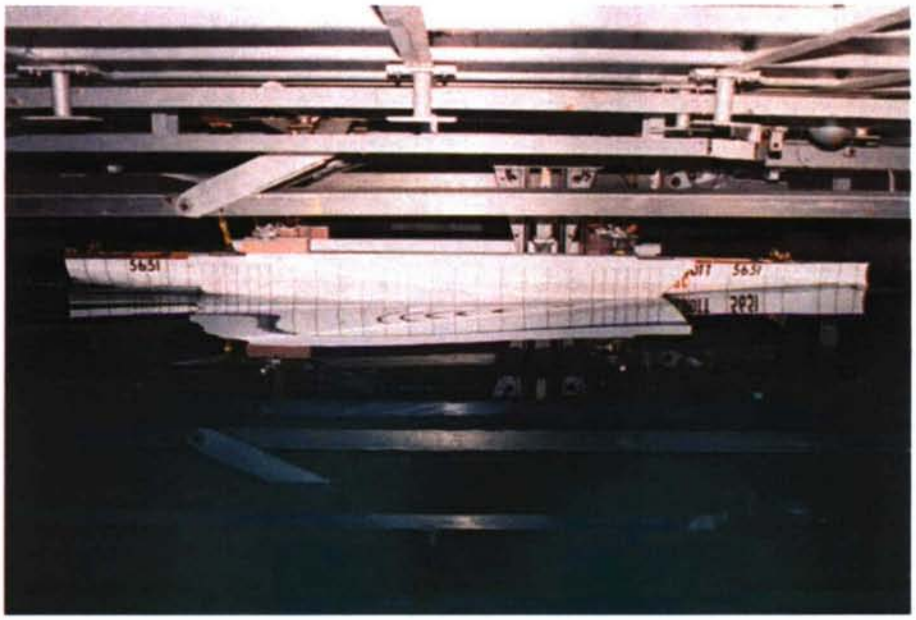


Figure 5. Continued.

Center Hull @ 11.5 m Draft
Side Hulls in Aft Longitudinal & Middle Transverse Location @ 7.5 m Drafts - 35 Knots

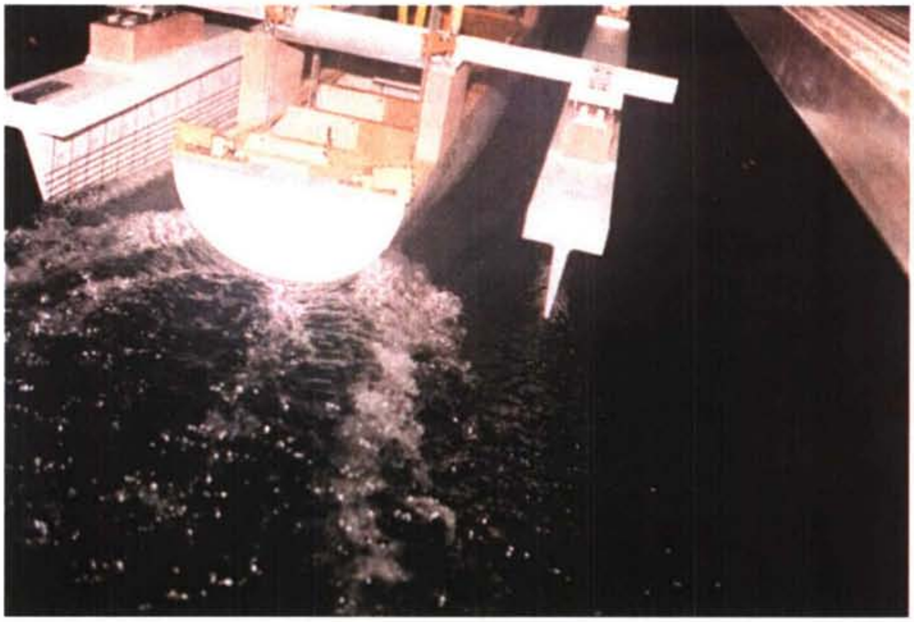


Figure 5. Continued.

Center Hull @ 11.5 m Draft
Side Hulls in Aft Longitudinal & Middle Transverse Location @ 7.5 m Drafts - 40 Knots

Figure 5. Continued.

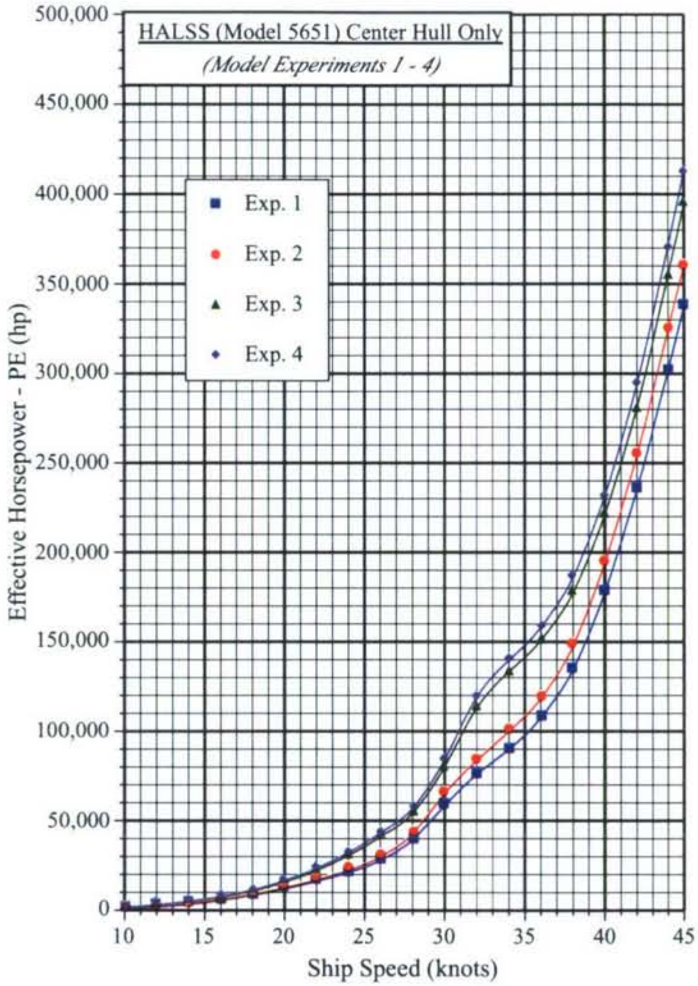


Figure 6. Predicted effective power (PE) for HALSS, various configurations of the center hull only, as represented by Model 5651.

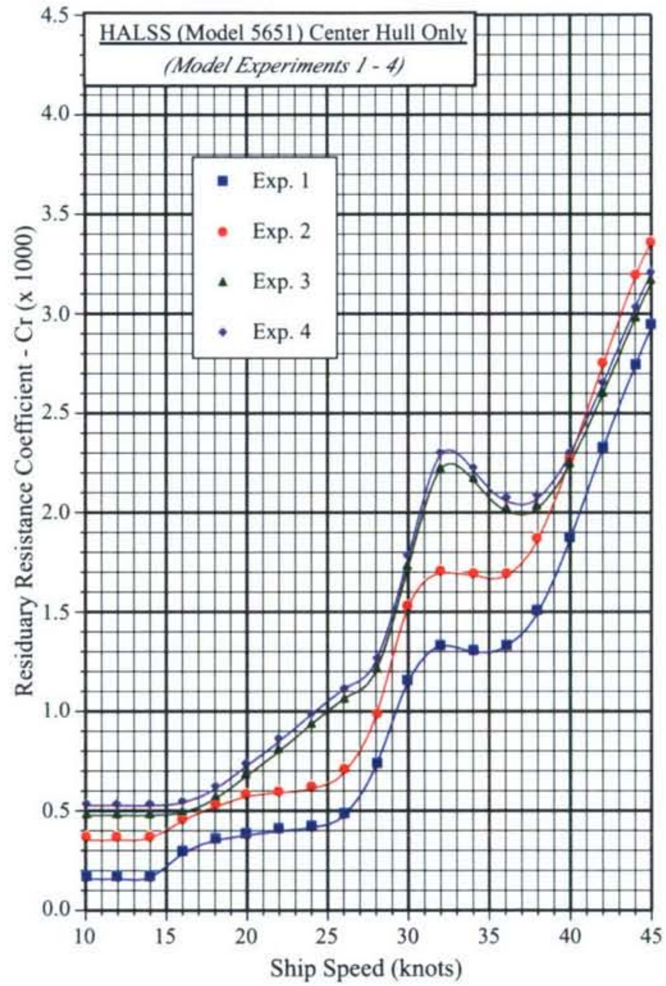


Figure 7. Residuary Resistance Coefficient (Cr) for HALSS, various configurations of the center hull only, as represented by Model 5651.

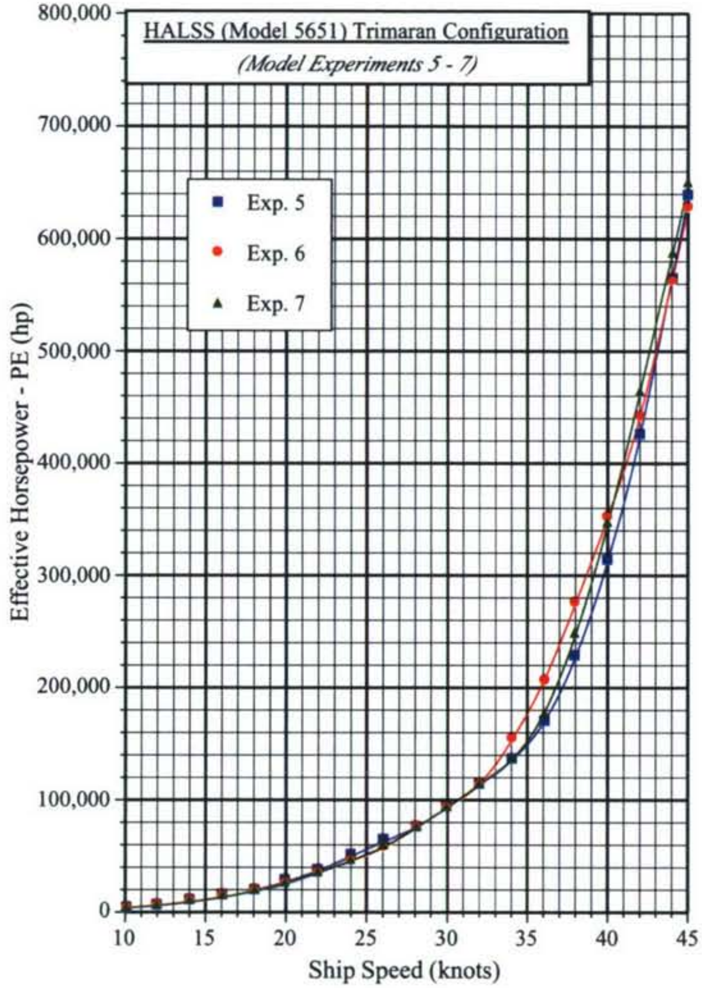


Figure 8. Predicted effective power (PE) for HALSS, trimaran configuration with side hulls at middle longitudinal and three transverse locations, as represented by Model 5651.

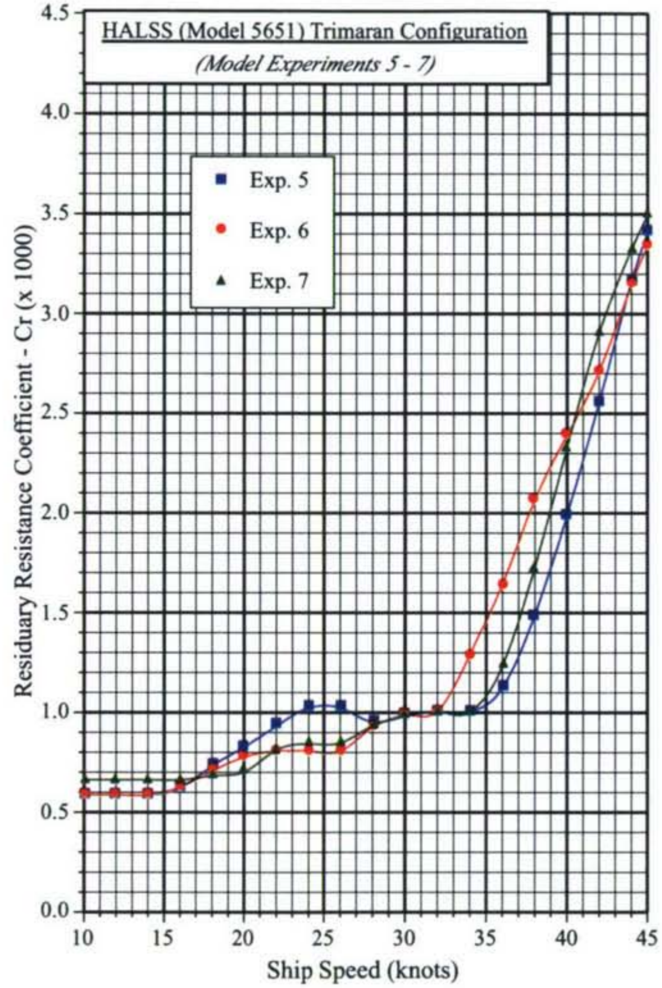


Figure 9. Residuary Resistance Coefficient (Cr) for HALSS, trimaran configuration with side hulls at middle longitudinal and three transverse locations, as represented by Model 5651.

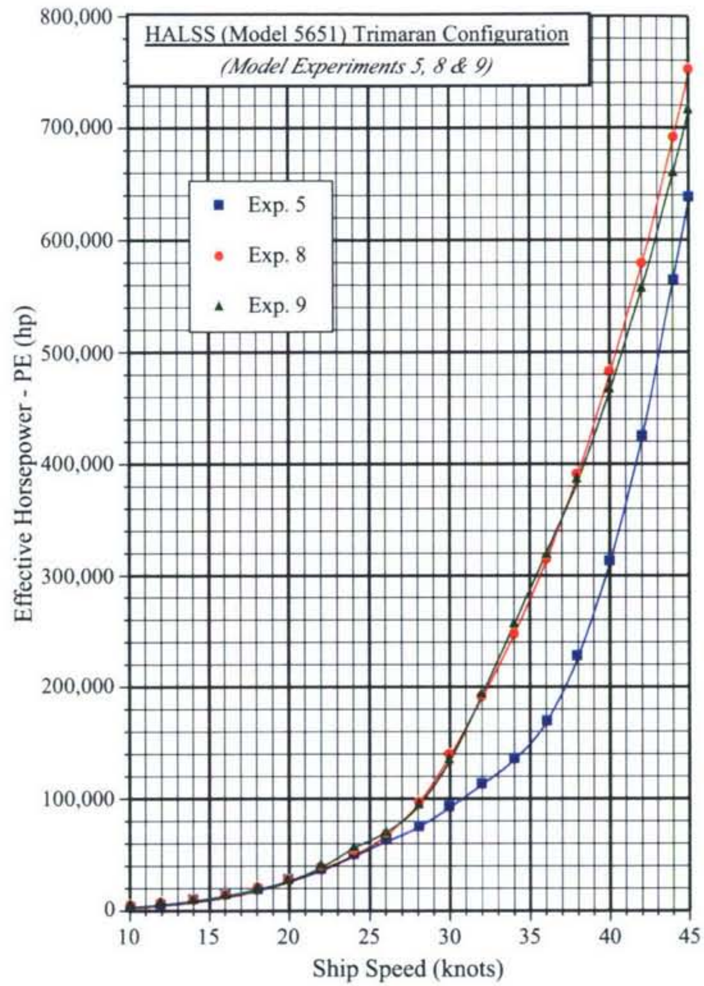


Figure 10. Predicted effective power (PE) for HALSS, trimaran configuration with side hulls at inboard transverse and three longitudinal locations, as represented by Model 5651.

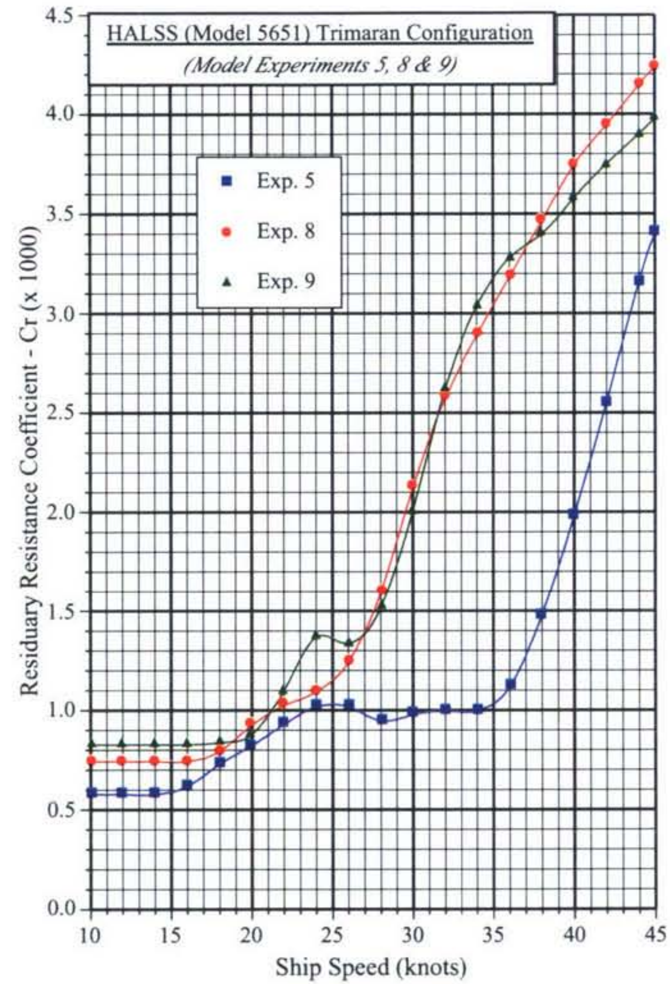


Figure 11. Residuary Resistance Coefficient (Cr) for HALSS, trimaran configuration with side hulls at inboard transverse and three longitudinal locations, as represented by Model 5651.

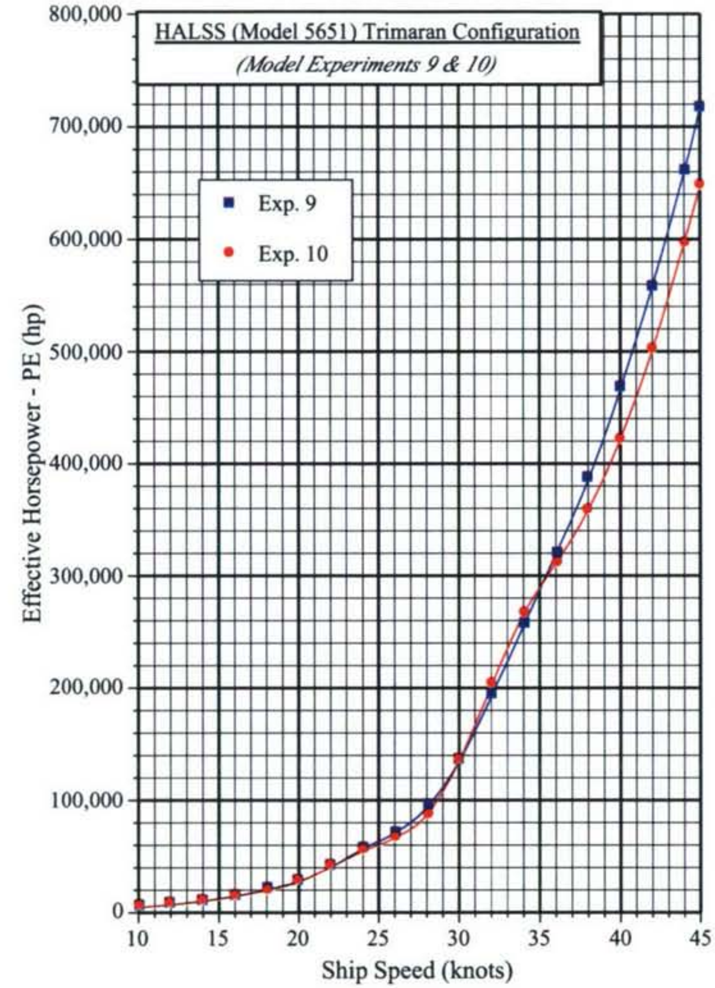


Figure 12. Predicted effective power (PE) for HALSS, trimaran configuration with side hulls at aft longitudinal and two transverse locations, as represented by Model 5651.

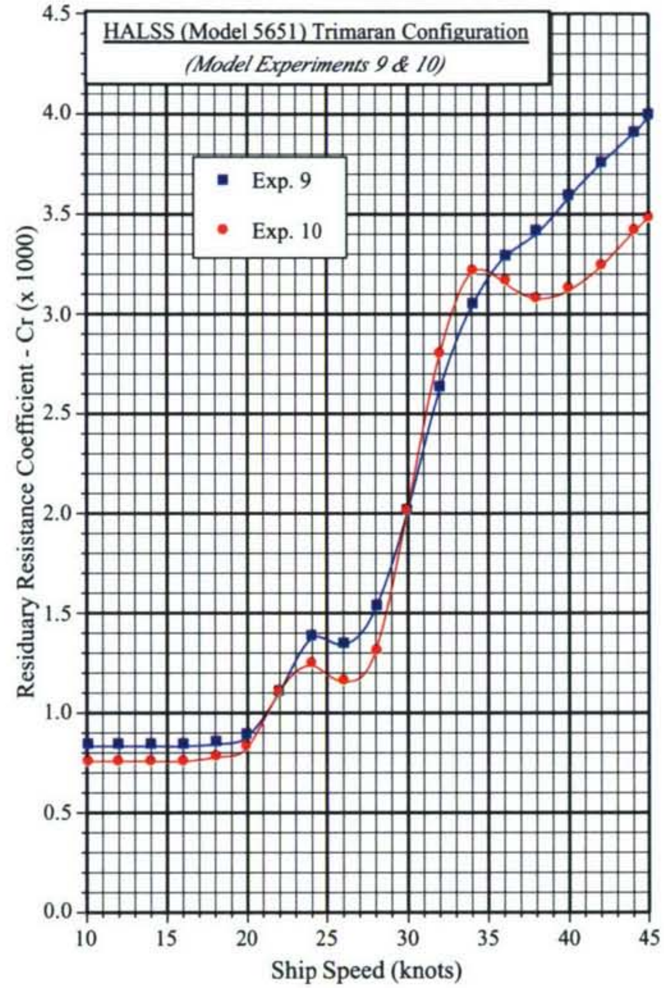


Figure 13. Residuary Resistance Coefficient (Cr) for HALSS, trimaran configuration with side hulls at aft longitudinal and two transverse locations, as represented by Model 5651.

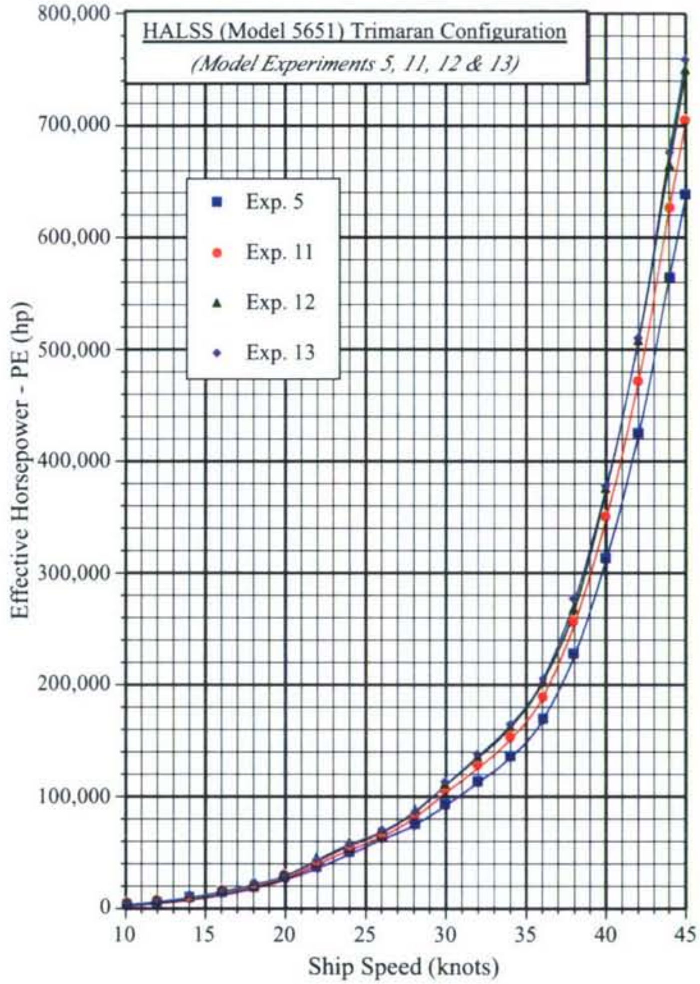


Figure 14. Predicted effective power (PE) for HALSS, trimaran configuration with side hulls at inboard transverse and middle longitudinal location with various drafts, as represented by Model 5651.

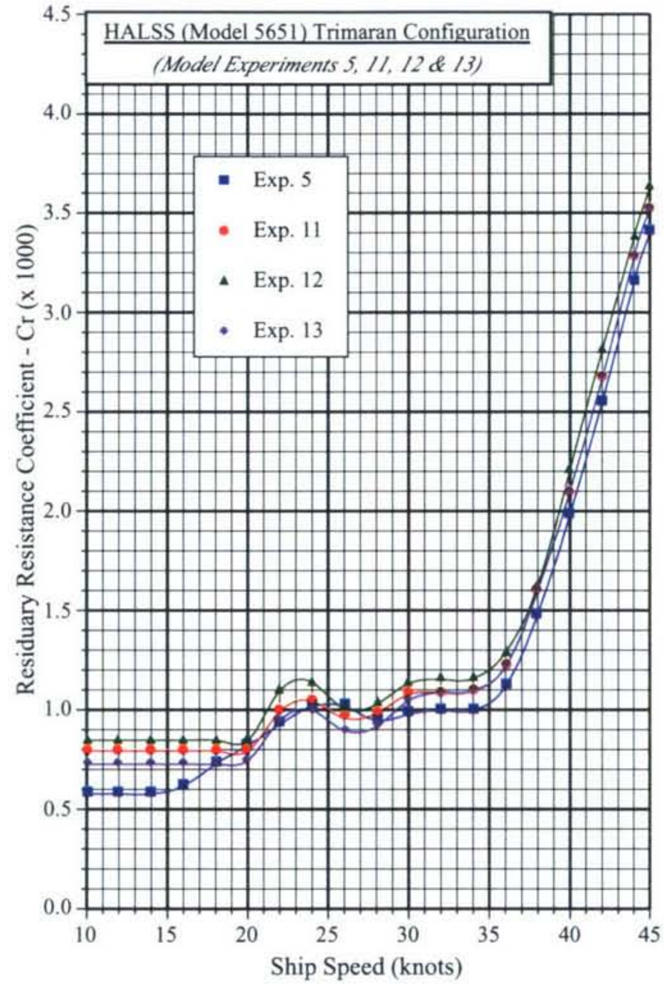


Figure 15. Residuary Resistance Coefficient (Cr) for HALSS, trimaran configuration with side hulls at inboard transverse and middle longitudinal location with various drafts, as represented by Model 5651.

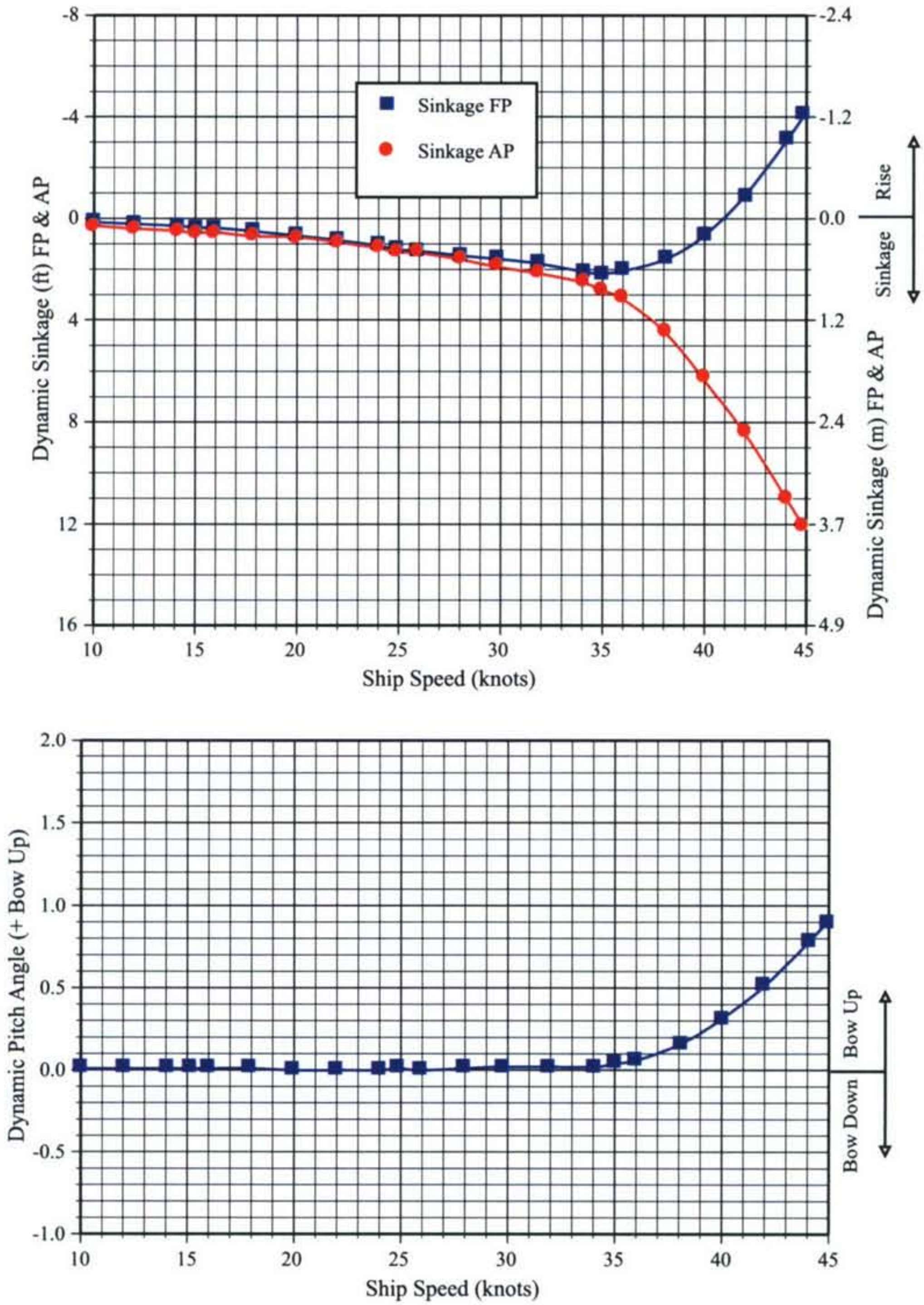


Figure 16. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and inboard transverse positions (Experiment 5).

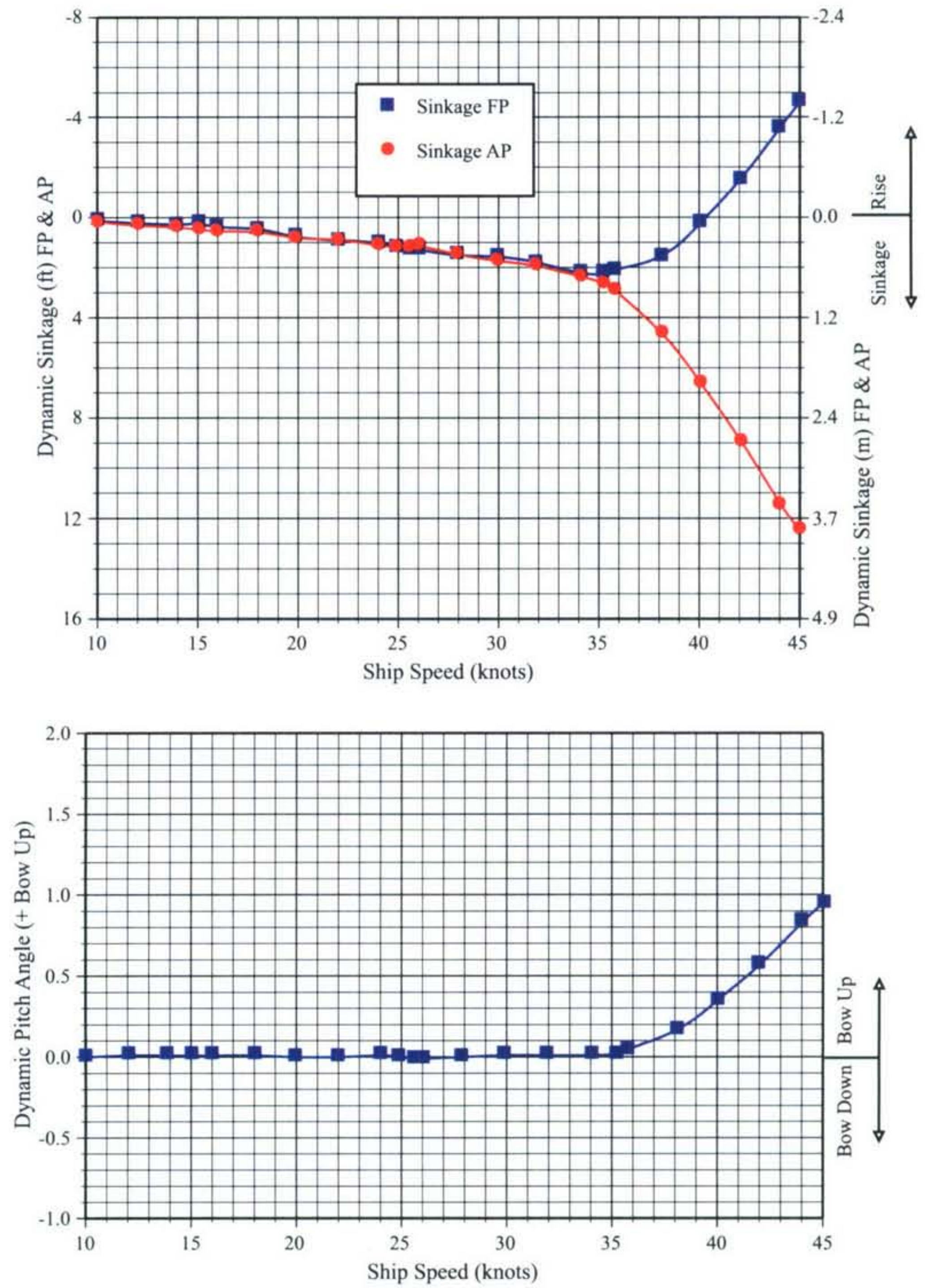
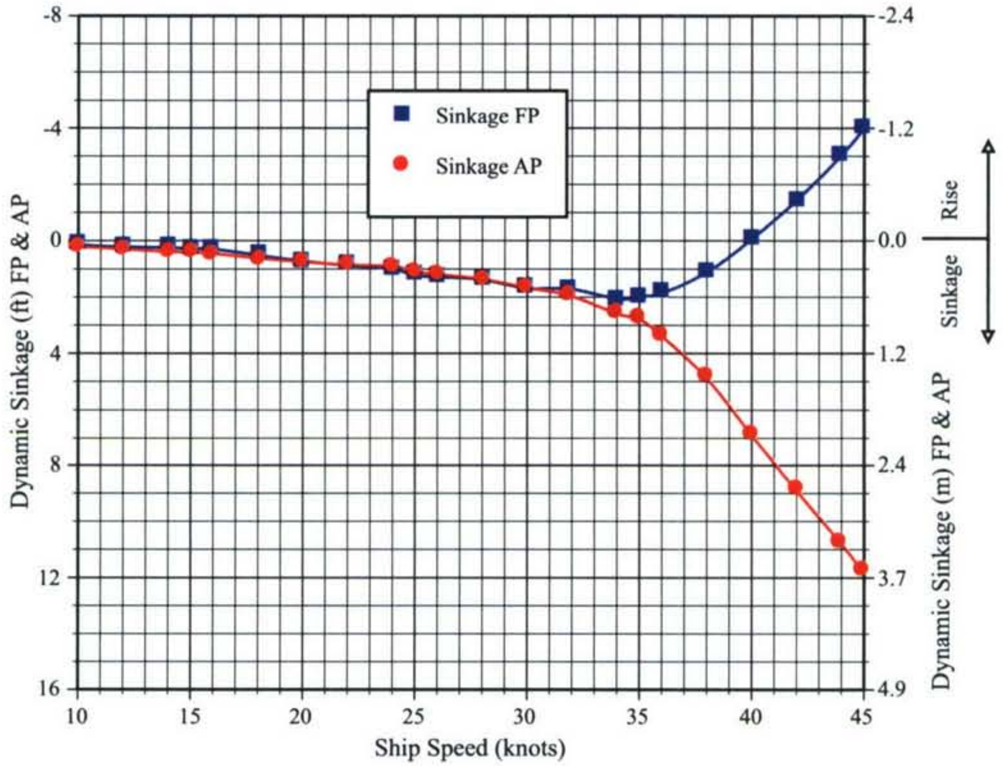


Figure 17. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and transverse positions (Experiment 6).



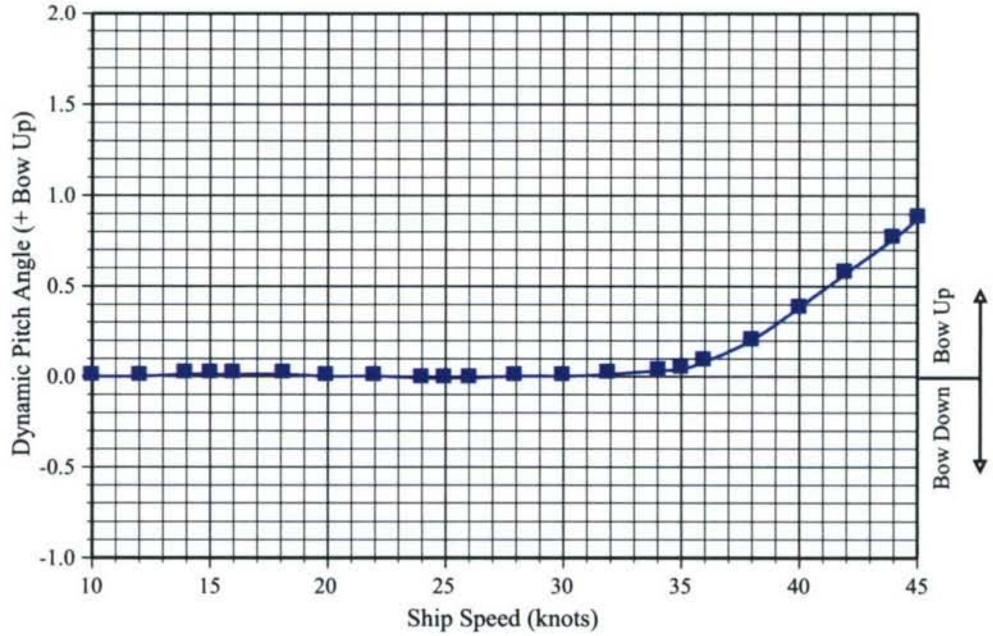


Figure 18. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and outboard transverse positions (Experiment 7).

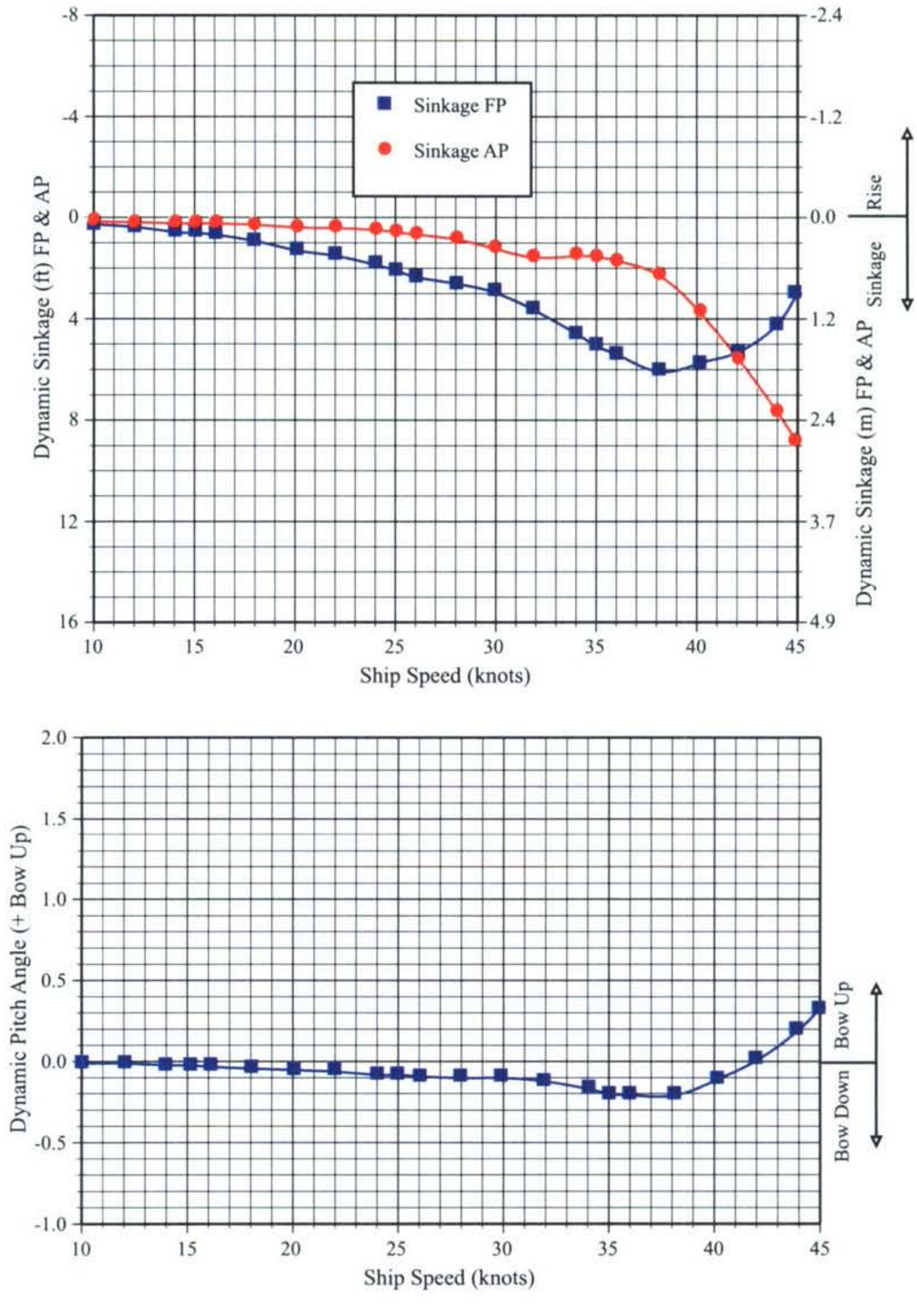


Figure 19. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with forward longitudinal and inboard transverse positions (Experiment 8).

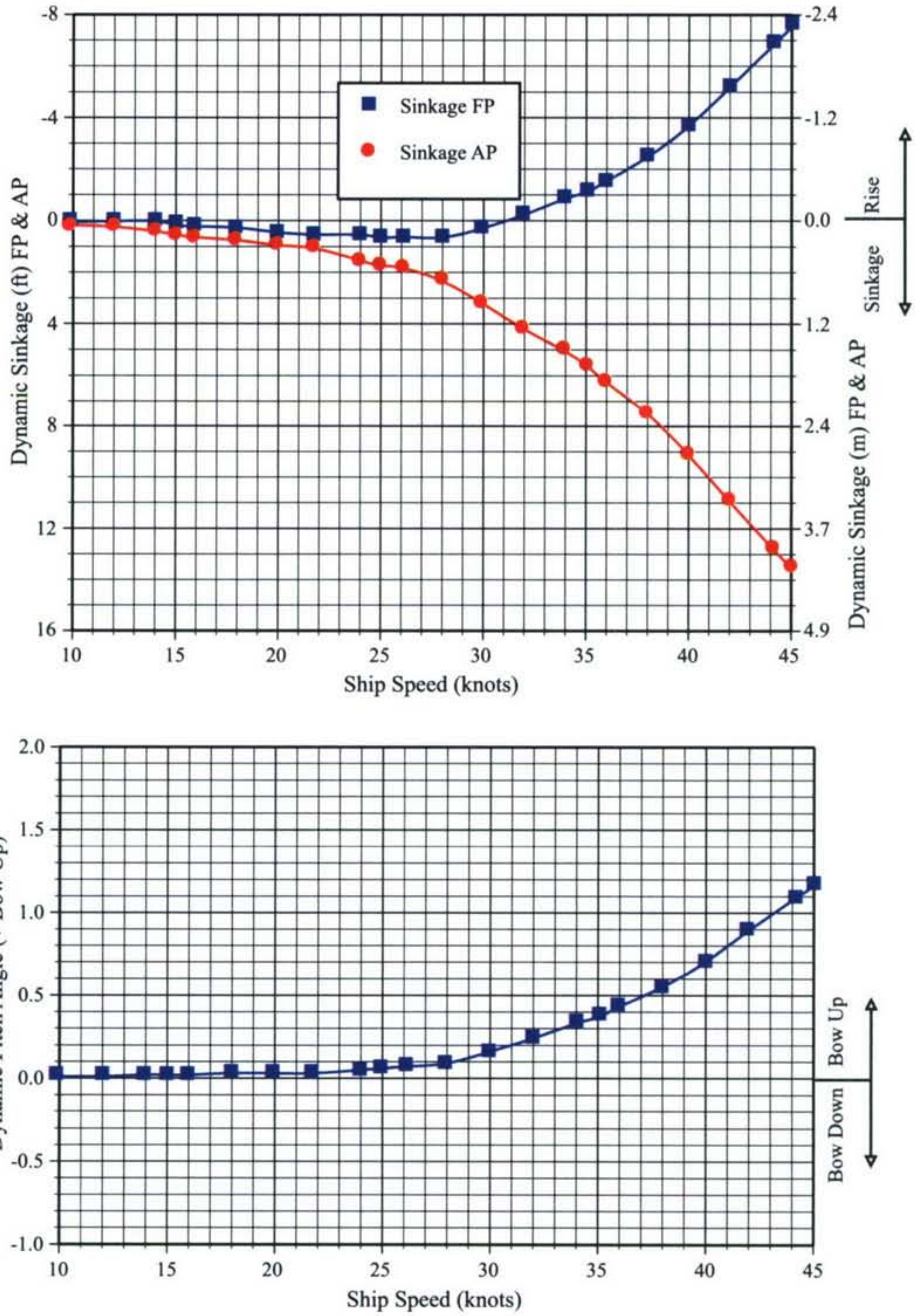
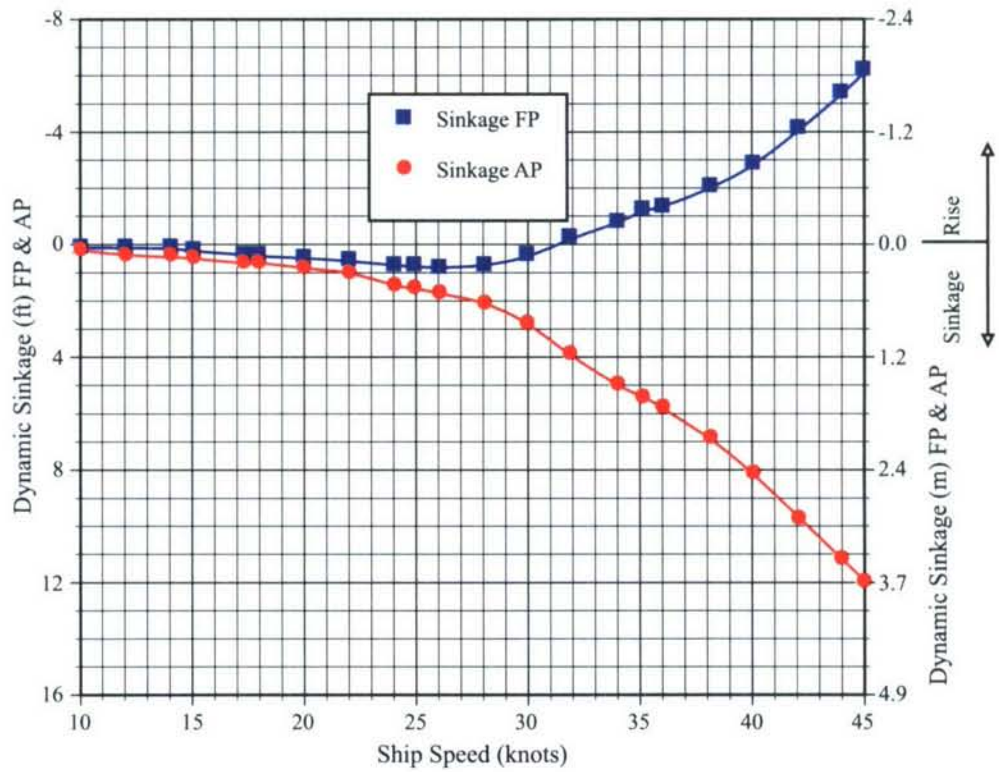


Figure 20. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with aft longitudinal and inboard transverse positions (Experiment 9).



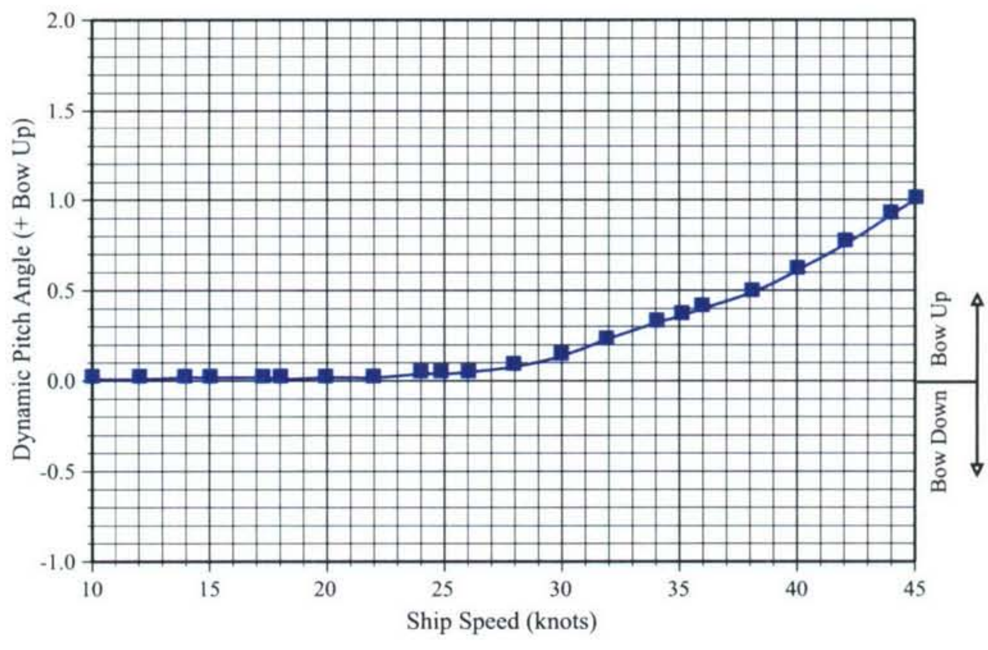


Figure 21. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with aft longitudinal and middle transverse positions (Experiment 10).

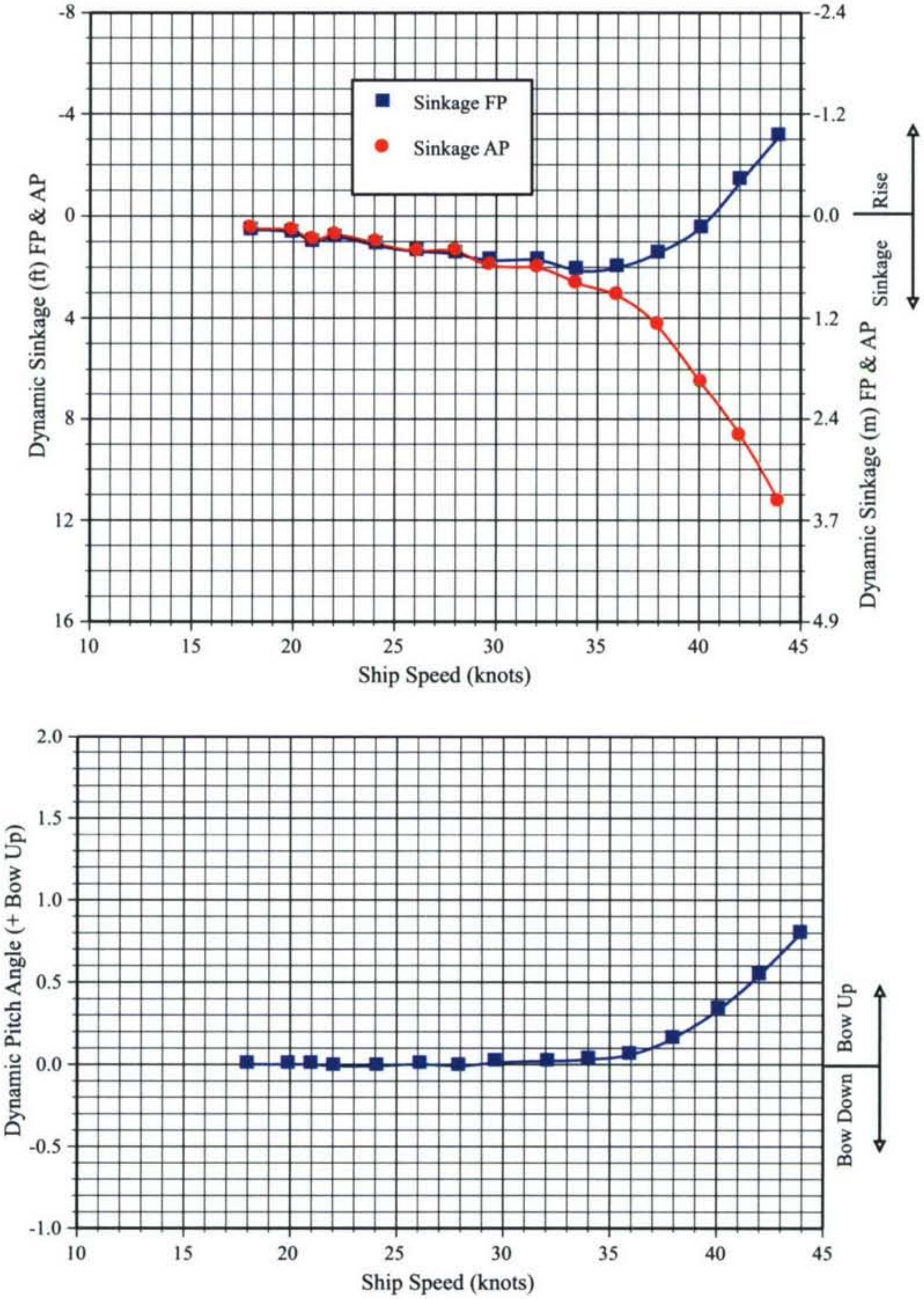


Figure 22. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 9.5 m drafts with middle longitudinal and inboard transverse positions (Experiment 11).

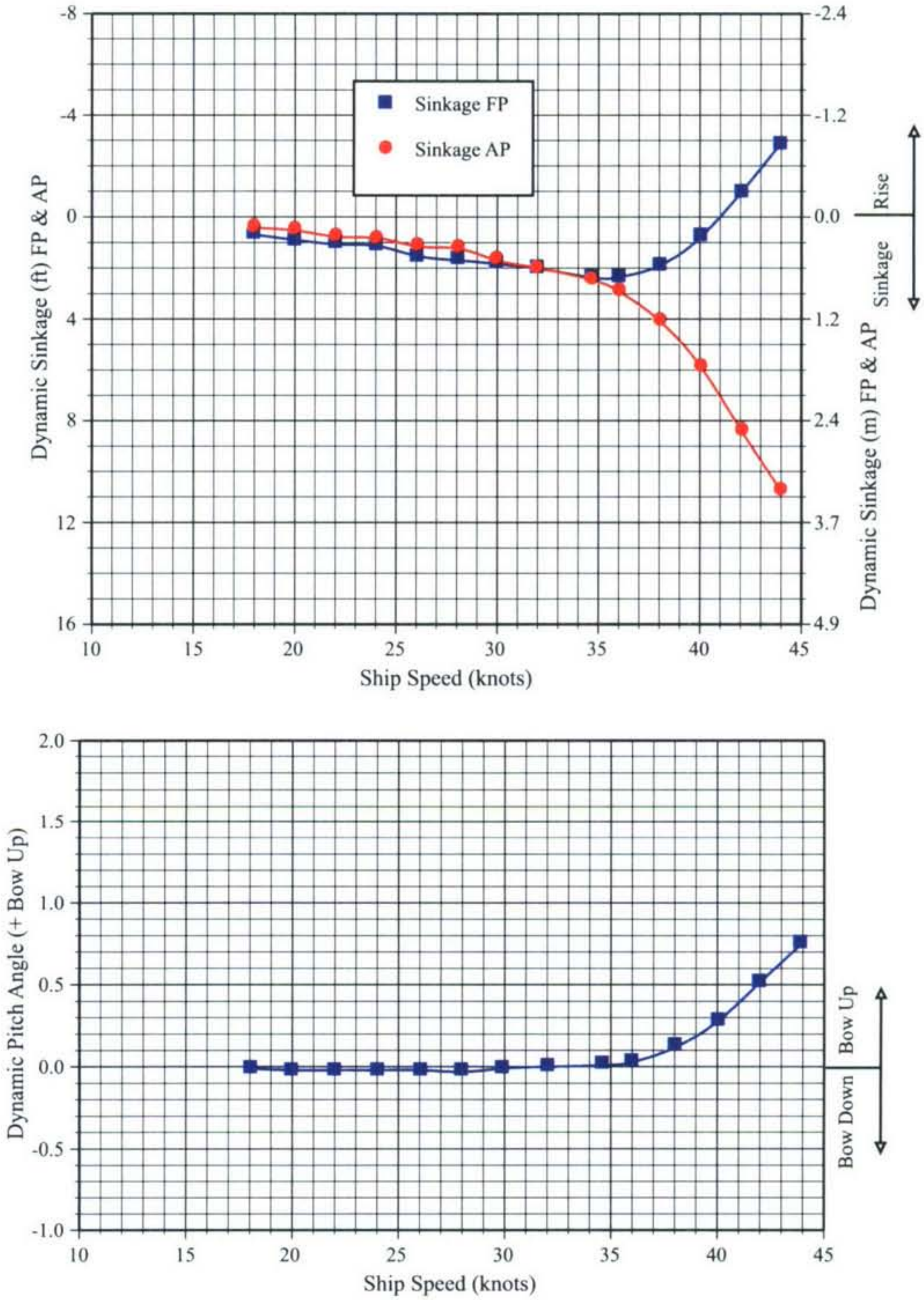
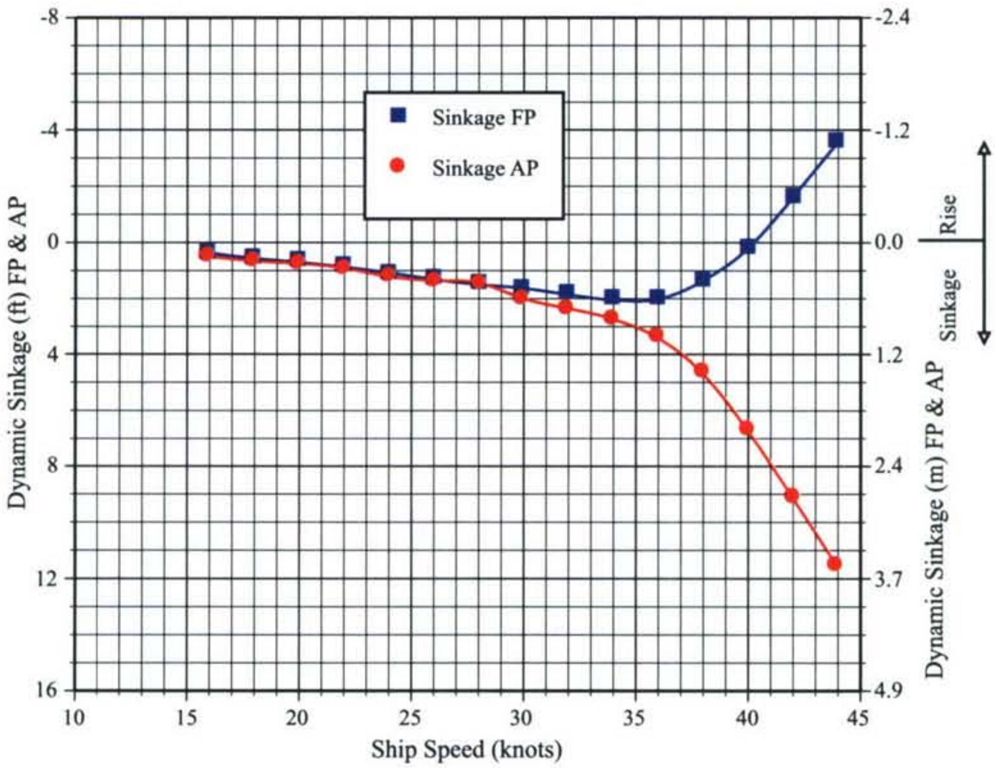


Figure 23. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 12.0 m draft, side hulls at 10.0 m drafts with middle longitudinal and inboard transverse positions (Experiment 12).



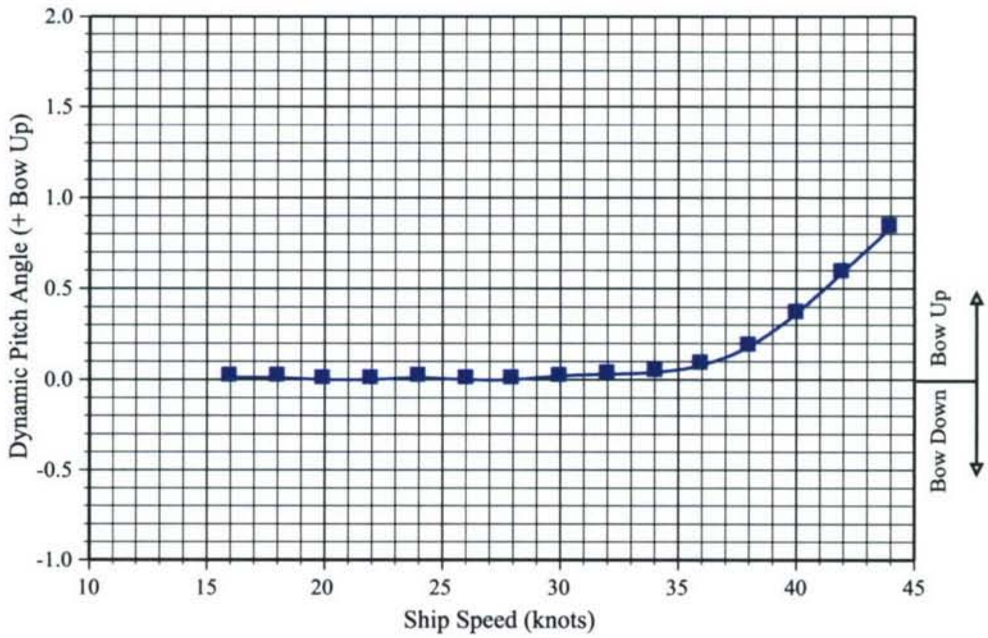


Figure 24. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 11.5 m drafts with middle longitudinal and inboard transverse positions (Experiment 13).

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Table 1. Model test plan completed for the HALSS trimaran utilizing Model 5651.

	Experiment Number	Experimental Conditions	Related Figures	Related Tables
Center Hull	**1**	Bare Hull, Bow Bulb, 11.5 m Draft	6, 7	2, 3
Center Hull	**2**	Bare Hull, Stem Bow, 11.5 m Draft	6, 7	2, 4
Center Hull	**3**	Twin Skegs, BowBulb, 11.5 m Draft	6, 7	2, 5
Center Hull	**4**	Twin Skegs, BowBulb, 12.0 m Draft	6, 7	2, 6
Trimaran with Skegs & Bow Bulb		*- Center Hull @ 11.5 m Draft, Side Hulls @ 7.5 m Draft & Middle Longitudinal Location -*		
Trimaran with Skegs & Bow Bulb	**5**	Side Hulls @ Inboard Transverse Location	8 - 11, 14 - 16	2, 7, 16
Trimaran with Skegs & Bow Bulb	**6**	Side Hulls @ Middle Transverse Location	8, 9, 17	2, 8, 17
Trimaran with Skegs & Bow Bulb	**7**	Side Hulls @ Outboard Transverse Location	8, 9, 18	2, 9, 18
Trimaran with Skegs & Bow Bulb		*- Side Hulls @ Fwd Longitudinal Location -*		
Trimaran with Skegs & Bow Bulb	**8**	Side Hulls @ Inboard Transverse Location	10, 11, 19	2, 10, 19
Trimaran with Skegs & Bow Bulb		*- Side Hulls @ Aft Longitudinal Location -*		
Trimaran with Skegs & Bow Bulb	**9**	Side Hulls @ Inboard Transverse Location	10 - 13, 20	2, 11, 20
Trimaran with Skegs & Bow Bulb	**10**	Side Hulls @ Middle Transverse Location	12, 13, 21	2, 12, 21
Trimaran with Skegs & Bow Bulb		*- Side Hulls @ Middle Longitudinal Location & Inboard Transverse Location -*		
Trimaran with Skegs & Bow Bulb	**11**	Center Hull @ 11.5 m Draft & Side Hulls @ 9.5 m Draft	14, 15, 22	2, 13, 22
Trimaran with Skegs & Bow Bulb	**12**	Center Hull @ 12 m Draft & Side Hulls @ 10 m Draft	14, 15, 23	2, 14, 23
Trimaran with Skegs & Bow Bulb		*- Side Hulls @ Middle Longitudinal Location & Inboard Transverse Location -*		
Trimaran with Skegs & Bow Bulb	**13**	Center Hull @ 11.5 m Draft & Side Hulls @ 11.5 m Draft	14, 15, 24	2, 15, 24

<u>Side Hull Longitudinal Locations (measured from Center Hull transom)</u>

	Ship (m)	Ship (ft)	Model (in)
Aft	0.0	0.0	0.0
Middle	50.0	164.0	36.5
Fwd	100.0	328.1	72.9

<u>Side Hull Transverse Locations (measured from Center Hull CL to Side Hull CL)</u>

	Ship (m)	Ship (ft)	Model (in)
Inboard	23.66	77.6	17.2
Middle	28.78	94.4	21.0
Outboard	35.0	114.8	25.5

Table 2. Ship/model test parameters for the HALSS trimaran represented by Model 5651.

	Center Hull Ship (m)	Center Hull Ship (ft)	Center Hull Model (ft)	Side Hulls Ship (m)	Side Hulls Ship (ft)	Side Hulls Model (ft)
LOA	316.0	1,036.7	19.2	192.6	631.9	11.7
LBP	305.0	1,000.7	18.5	---	---	---
Beam	25.0	82.0	1.52	4.9	16.1	0.3

Linear Scale Ratio λ 54.00

Correlation Allowance C_A 0.0000

	Exp. Number	Ship LWL (m)	Ship LWL (ft)	Model LWL (ft)	Ship Draft (m)	Ship Draft (ft)	Model Draft (m)	Model Draft (ft)	Ship Wetted Surface (m²)	Ship Wetted Surface (ft²)	Model Wetted Surface (ft²)	Ship Δ (tonnes)	Ship Δ (LT)	Model Δ (lb)
Center Hull Only	1	289.8	950.8	17.6	11.5	37.7	0.21	0.70	9,455.8	101,781.4	34.904	48,053.6	47,296.9	654
	2	282.3	926.2	17.2	11.5	37.7	0.21	0.70	9,163.3	98,632.9	33.825	47,689.3	46,938.3	649
	3	289.8	950.8	17.6	11.5	37.7	0.21	0.70	10,489.8	112,910.9	38.721	50,889.4	50,088.0	693
	4	299.9	984.0	18.2	12.0	39.4	0.22	0.73	10,858.2	116,876.3	40.081	53,789.3	52,942.2	732
Full Trimaran with Skegs & Bow Bulb	5	289.8	950.8	17.6	11.5	37.7	0.21	0.70	16,028.0	172,524.0	59.165	60,343.0	59,392.7	821
	6	289.8	950.8	17.6	11.5	37.7	0.21	0.70	16,028.0	172,524.0	59.165	60,343.0	59,392.7	821
	7	289.8	950.8	17.6	11.5	37.7	0.21	0.70	16,028.0	172,524.0	59.165	60,343.0	59,392.7	821
	8	289.8	950.8	17.6	11.5	37.7	0.21	0.70	16,028.0	172,524.0	59.165	60,343.0	59,392.7	821
	9	289.8	950.8	17.6	11.5	37.7	0.21	0.70	16,028.0	172,524.0	59.165	60,343.0	59,392.7	821
	10	289.8	950.8	17.6	11.5	37.7	0.21	0.70	16,028.0	172,524.0	59.165	60,343.0	59,392.7	821
	11	289.8	950.8	17.6	11.5	37.7	0.21	0.70	17,304.0	186,258.7	63.875	61,987.0	61,010.8	844
	12	299.9	984.0	18.2	12.0	39.4	0.22	0.73	17,992.0	193,664.3	66.414	65,300.0	64,271.7	889
	13	289.8	950.8	17.6	11.5	37.7	0.21	0.70	18,650.0	200,746.9	68.843	63,689.0	62,686.0	867

Table 3. Predicted effective power for the HALSS trimaran with 11.5 m draft, bare center hull only fitted with the bow bulb, as represented by Model 5651 (PE Experiment 1).

EHP RESULTS FROM EXPERIMENT NUMBER = 1
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull Only @ 11.5 m Draft, Bare Hull, Bow Bulb

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	101,781.3 FT^2 (9456.0 M^2)	34.90 FT^2 (3.24 M^2)
DISPLACEMENT	47,296.9 LT (48054. T)	0.29 LT (0.29 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	1,460.0	1,088.7	1,318.3	983.1	0.096	0.324	0.160
12	6.17	2,472.9	1,844.0	2,228.1	1,661.5	0.116	0.389	0.160
14	7.20	3,886.1	2,897.9	3,473.0	2,589.8	0.135	0.454	0.170
16	8.23	6,139.5	4,578.2	5,102.2	3,804.7	0.154	0.519	0.286
18	9.26	8,981.8	6,697.7	7,163.9	5,342.1	0.174	0.584	0.352
20	10.29	12,397.8	9,245.1	9,705.9	7,237.7	0.193	0.649	0.380
22	11.32	16,546.8	12,338.9	12,775.2	9,526.5	0.212	0.713	0.400
24	12.35	21,547.6	16,068.0	16,418.5	12,243.2	0.232	0.778	0.419
26	13.38	28,168.1	21,004.9	20,681.9	15,422.5	0.251	0.843	0.481
28	14.40	39,821.0	29,694.5	25,611.3	19,098.3	0.270	0.908	0.731
30	15.43	58,747.2	43,807.8	31,252.0	23,304.6	0.289	0.973	1.150
32	16.46	76,241.2	56,853.0	37,649.2	28,075.0	0.309	1.038	1.330
34	17.49	90,197.5	67,260.3	44,847.7	33,442.9	0.328	1.103	1.303
36	18.52	107,798.8	80,385.6	52,891.9	39,441.5	0.347	1.167	1.329
38	19.55	134,710.9	100,453.9	61,826.1	46,103.7	0.367	1.232	1.500
40	20.58	177,729.2	132,532.6	71,694.3	53,462.4	0.386	1.297	1.871
42	21.61	235,008.2	175,245.6	82,540.2	61,550.2	0.405	1.362	2.324
44	22.64	301,014.3	224,466.3	94,407.4	70,399.6	0.425	1.427	2.739
45	23.15	337,488.7	251,665.3	100,737.4	75,119.9	0.434	1.459	2.934

Table 4. Predicted effective power for the HALSS trimaran with 11.5 m draft, bare center hull only fitted with the stem bulb, as represented by Model 5651 (PE Experiment 2)

EHP RESULTS FROM EXPERIMENT NUMBER = 2
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull Only @ 11.5 m Draft, Bare Hull, Stem Bow

	SHIP	MODEL
LENGTH	926.18 FT (282.3 M)	17.15 FT (5.228 M)
WETTED SURFACE	98,632.9 FT^2 (9163.0 M^2)	33.82 FT^2 (3.14 M^2)
DISPLACEMENT	46,938.8 LT (47689. T)	0.29 LT (0.29 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	1,590.6	1,186.1	1,281.7	955.7	0.098	0.329	0.360
12	6.17	2,699.9	2,013.3	2,166.1	1,615.2	0.117	0.394	0.360
14	7.20	4,249.8	3,169.1	3,376.3	2,517.7	0.137	0.460	0.371
16	8.23	6,562.7	4,893.8	4,959.9	3,698.6	0.156	0.526	0.456
18	9.26	9,596.4	7,156.0	6,964.0	5,193.0	0.176	0.591	0.526
20	10.29	13,402.8	9,994.5	9,434.8	7,035.5	0.196	0.657	0.578
22	11.32	17,882.4	13,334.9	12,418.2	9,260.2	0.215	0.723	0.598
24	12.35	23,302.5	17,376.7	15,959.4	11,900.9	0.235	0.789	0.619
26	13.38	30,661.1	22,864.0	20,103.4	14,991.1	0.254	0.854	0.700
28	14.40	43,543.9	32,470.6	24,894.5	18,563.9	0.274	0.920	0.990
30	15.43	65,872.8	49,121.3	30,377.1	22,652.2	0.293	0.986	1.532
32	16.46	84,397.5	62,935.2	36,594.8	27,288.7	0.313	1.051	1.700
34	17.49	100,591.5	75,011.0	43,591.2	32,505.9	0.332	1.117	1.690
36	18.52	119,031.9	88,762.1	51,409.5	38,336.1	0.352	1.183	1.689
38	19.55	148,240.3	110,542.8	60,092.8	44,811.2	0.372	1.249	1.872
40	20.58	194,627.6	145,133.8	69,683.7	51,963.1	0.391	1.314	2.275
42	21.61	254,744.2	189,962.7	80,224.8	59,823.6	0.411	1.380	2.745
44	22.64	324,798.0	242,201.9	91,758.4	68,424.2	0.430	1.446	3.188
45	23.15	360,731.1	268,997.1	97,910.4	73,011.8	0.440	1.479	3.361

Table 5. Predicted effective power for the HALSS trimaran with 11.5 m draft, center hull only fitted with twin skegs and bow bulb, as represented by Model 5651 (PE Experiment 3).

EHP RESULTS FROM EXPERIMENT NUMBER = 3
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull Only @ 11.5 m Draft, with Skeg, Bow Bulb

	SHIP	MODEL
LENGTH	950.82 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	112,910.9 FT^2 (10490.0 M^2)	38.72 FT^2 (3.60 M^2)
DISPLACEMENT	50,088.0 LT (50889. T)	0.32 LT (0.32 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO	54.000
ITTC FRICTION LINE	
CORRELATION ALLOWANCE (CA)	0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	1,934.0	1,442.2	1,462.5	1,090.6	0.096	0.324	0.480
12	6.17	3,286.6	2,450.8	2,471.8	1,843.2	0.116	0.389	0.480
14	7.20	5,146.7	3,837.9	3,852.8	2,873.1	0.135	0.454	0.480
16	8.23	7,651.9	5,706.0	5,660.2	4,220.8	0.154	0.519	0.495
18	9.26	11,172.9	8,331.6	7,947.4	5,926.4	0.174	0.584	0.563
20	10.29	16,111.4	12,014.2	10,767.4	8,029.2	0.193	0.649	0.680
22	11.32	22,571.8	16,831.8	14,172.3	10,568.3	0.212	0.713	0.803
24	12.35	30,952.2	23,081.0	18,214.1	13,582.2	0.232	0.778	0.938
26	13.38	41,331.9	30,821.2	22,943.7	17,109.2	0.251	0.843	1.065
28	14.40	54,462.3	40,612.5	28,412.2	21,187.0	0.270	0.908	1.208
30	15.43	80,476.1	60,011.0	34,669.9	25,853.3	0.289	0.973	1.727
32	16.46	113,228.1	84,434.2	41,766.7	31,145.4	0.309	1.038	2.220
34	17.49	133,459.9	99,521.0	49,752.4	37,100.4	0.328	1.103	2.168
36	18.52	150,937.7	112,554.2	58,676.4	43,755.0	0.347	1.167	2.013
38	19.55	177,742.9	132,542.8	68,587.7	51,145.8	0.367	1.232	2.025
40	20.58	221,057.1	164,842.2	79,535.1	59,309.3	0.386	1.297	2.251
42	21.61	280,797.0	209,390.3	91,567.2	68,281.6	0.405	1.362	2.600
44	22.64	354,101.3	264,053.3	104,732.2	78,098.8	0.425	1.427	2.980
45	23.15	394,628.4	294,274.4	111,754.5	83,335.3	0.434	1.459	3.160

Table 6. Predicted effective power for the HALSS trimaran with 12.0 m draft, center hull only fitted with twin skegs and bow bulb, as represented by Model 5651 (PE Experiment 4).

EHP RESULTS FROM EXPERIMENT NUMBER = 4
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull Only @ 12.0 m Draft, with Skeg, Bow Bulb

	SHIP	MODEL
LENGTH	984.02 FT (299.9 M)	18.22 FT (5.554 M)
WETTED SURFACE	116,876.3 FT^2 (10858.0 M^2)	40.08 FT^2 (3.72 M^2)
DISPLACEMENT	52,942.2 LT (53789. T)	0.34 LT (0.34 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	2,046.5	1,526.0	1,507.5	1,124.2	0.095	0.319	0.530
12	6.17	3,479.2	2,594.5	2,548.0	1,900.0	0.114	0.383	0.530
14	7.20	5,450.6	4,064.5	3,971.8	2,961.8	0.133	0.446	0.530
16	8.23	8,105.1	6,043.9	5,835.1	4,351.2	0.152	0.510	0.545
18	9.26	11,828.5	8,820.5	8,193.2	6,109.7	0.171	0.574	0.613
20	10.29	17,039.1	12,706.1	11,100.7	8,277.8	0.190	0.638	0.730
22	11.32	23,847.2	17,782.9	14,611.4	10,895.7	0.209	0.701	0.853
24	12.35	32,667.0	24,359.8	18,778.8	14,003.3	0.228	0.765	0.988
26	13.38	43,583.0	32,499.9	23,655.5	17,639.9	0.247	0.829	1.115
28	14.40	57,375.2	42,784.6	29,294.1	21,844.6	0.266	0.893	1.258
30	15.43	84,534.2	63,037.1	35,746.6	26,656.2	0.285	0.956	1.777
32	16.46	119,467.8	89,087.1	43,064.5	32,113.2	0.304	1.020	2.293
34	17.49	139,944.4	104,356.5	51,299.0	38,253.7	0.323	1.084	2.218
36	18.52	158,374.5	118,099.9	60,501.1	45,115.7	0.341	1.148	2.063
38	19.55	186,499.8	139,072.9	70,721.5	52,737.0	0.360	1.211	2.075
40	20.58	231,756.2	172,820.6	82,010.4	61,155.1	0.379	1.275	2.301
42	21.61	294,059.9	219,280.4	94,417.9	70,407.4	0.398	1.339	2.650
44	22.64	370,451.2	276,245.4	107,993.8	80,531.0	0.417	1.403	3.030
45	23.15	412,676.3	307,732.7	115,235.5	85,931.1	0.427	1.435	3.210

Table 7. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and inboard transverse positions (PE Experiment 5).

EHP RESULTS FROM EXPERIMENT NUMBER = 5
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 7.5 m Draft,
Middle Longitudinal Location,
and Inboard Transverse Location.

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	172,524.0 FT^2 (16,028.0 M^2)	59.16 FT^2 (5.50 M^2)
DISPLACEMENT	59,392.7 LT (60,343.0 T)	0.37 LT (0.37 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,105.3	2,315.6	2,234.7	1,666.4	0.096	0.324	0.580
12	6.17	5,281.2	3,938.2	3,776.8	2,816.3	0.116	0.389	0.580
14	7.20	8,275.9	6,171.4	5,887.0	4,390.0	0.135	0.454	0.580
16	8.23	12,460.5	9,291.8	8,648.6	6,449.3	0.154	0.519	0.620
18	9.26	18,533.8	13,820.6	12,143.4	9,055.3	0.174	0.584	0.730
20	10.29	26,358.9	19,655.8	16,452.2	12,268.4	0.193	0.649	0.825
22	11.32	36,518.9	27,232.2	21,654.9	16,148.1	0.212	0.713	0.930
24	12.35	48,995.6	36,536.0	27,830.6	20,753.2	0.232	0.778	1.020
26	13.38	61,966.9	46,208.7	35,057.4	26,142.3	0.251	0.843	1.020
28	14.40	74,715.8	55,715.6	43,413.1	32,373.1	0.270	0.908	0.950
30	15.43	92,691.4	69,120.0	52,974.6	39,503.2	0.289	0.973	0.980
32	16.46	113,003.6	84,266.8	63,818.4	47,589.4	0.309	1.038	1.000
34	17.49	135,016.1	100,681.5	76,020.4	56,688.4	0.328	1.103	1.000
36	18.52	168,090.9	125,345.4	89,655.9	66,856.4	0.347	1.167	1.120
38	19.55	226,698.2	169,048.9	104,800.1	78,149.4	0.367	1.232	1.480
40	20.58	311,735.9	232,461.4	121,527.5	90,623.0	0.386	1.297	1.980
42	21.61	423,490.1	315,796.5	139,912.1	104,332.4	0.405	1.362	2.550
44	22.64	563,433.4	420,152.2	160,027.9	119,332.8	0.425	1.427	3.155
45	23.15	635,809.1	474,122.8	170,757.8	127,334.1	0.434	1.459	3.400

Table 8. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and transverse positions (PE Experiment 6).

EHP RESULTS FROM EXPERIMENT NUMBER = 6
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 7.5 m Draft, Middle Longitudinal Location, Middle Transverse Location.

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	172,524.0 FT^2 (16,028.0 M^2)	59.16 FT^2 (5.50 M^2)
DISPLACEMENT	59,392.7 LT (60,343.0 T)	0.37 LT (0.37 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,105.3	2,315.6	2,234.7	1,666.4	0.096	0.324	0.580
12	6.17	5,281.2	3,938.2	3,776.8	2,816.3	0.116	0.389	0.580
14	7.20	8,275.9	6,171.4	5,887.0	4,390.0	0.135	0.454	0.580
16	8.23	12,460.5	9,291.8	8,648.6	6,449.3	0.154	0.519	0.620
18	9.26	18,271.1	13,624.8	12,143.4	9,055.3	0.174	0.584	0.700
20	10.29	25,698.5	19,163.3	16,452.2	12,268.4	0.193	0.649	0.770
22	11.32	34,441.2	25,682.8	21,654.9	16,148.1	0.212	0.713	0.800
24	12.35	44,430.6	33,131.9	27,830.6	20,753.2	0.232	0.778	0.800
26	13.38	56,162.8	41,880.6	35,057.4	26,142.3	0.251	0.843	0.800
28	14.40	73,727.3	54,978.4	43,413.1	32,373.1	0.270	0.908	0.920
30	15.43	92,691.4	69,120.0	52,974.6	39,503.2	0.289	0.973	0.980
32	16.46	113,003.6	84,266.8	63,818.4	47,589.4	0.309	1.038	1.000
34	17.49	151,535.0	112,999.6	76,020.4	56,688.4	0.328	1.103	1.280
36	18.52	203,806.9	151,978.8	89,655.9	66,856.4	0.347	1.167	1.630
38	19.55	273,645.5	204,057.4	104,800.1	78,149.4	0.367	1.232	2.050
40	20.58	350,161.8	261,115.6	121,527.5	90,623.0	0.386	1.297	2.380
42	21.61	440,171.2	328,235.6	139,912.1	104,332.4	0.405	1.362	2.700
44	22.64	560,876.1	418,245.2	160,027.9	119,332.8	0.425	1.427	3.135
45	23.15	626,234.5	466,983.0	170,757.8	127,334.1	0.434	1.459	3.330

Table 9. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and outboard transverse positions (PE Experiment 7).

EHP RESULTS FROM EXPERIMENT NUMBER = 7
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 7.5 m Draft, Middle Longitudinal Location, Outboard Transverse Location.

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	172,524.0 FT^2 (16,028.0 M^2)	59.16 FT^2 (5.50 M^2)
DISPLACEMENT	59,392.7 LT (60,343.0 T)	0.37 LT (0.37 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,225.3	2,405.1	2,234.7	1,666.4	0.096	0.324	0.660
12	6.17	5,488.7	4,092.9	3,776.8	2,816.3	0.116	0.389	0.660
14	7.20	8,605.4	6,417.1	5,887.0	4,390.0	0.135	0.454	0.660
16	8.23	12,706.4	9,475.2	8,648.6	6,449.3	0.154	0.519	0.660
18	9.26	18,096.1	13,494.2	12,143.4	9,055.3	0.174	0.584	0.680
20	10.29	24,857.9	18,536.5	16,452.2	12,268.4	0.193	0.649	0.700
22	11.32	34,601.0	25,802.0	21,654.9	16,148.1	0.212	0.713	0.810
24	12.35	45,260.6	33,750.8	27,830.6	20,753.2	0.232	0.778	0.840
26	13.38	57,350.0	42,765.9	35,057.4	26,142.3	0.251	0.843	0.845
28	14.40	74,056.8	55,224.2	43,413.1	32,373.1	0.270	0.908	0.930
30	15.43	92,691.4	69,120.0	52,974.6	39,503.2	0.289	0.973	0.980
32	16.46	113,003.6	84,266.8	63,818.4	47,589.4	0.309	1.038	1.000
34	17.49	135,016.1	100,681.5	76,020.4	56,688.4	0.328	1.103	1.000
36	18.52	175,794.4	131,089.8	89,655.9	66,856.4	0.347	1.167	1.230
38	19.55	246,465.5	183,789.3	104,800.1	78,149.4	0.367	1.232	1.720
40	20.58	344,397.9	256,817.5	121,527.5	90,623.0	0.386	1.297	2.320
42	21.61	462,412.6	344,821.0	139,912.1	104,332.4	0.405	1.362	2.900
44	22.64	584,530.7	435,884.5	160,027.9	119,332.8	0.425	1.427	3.320
45	23.15	648,119.3	483,302.5	170,757.8	127,334.1	0.434	1.459	3.490

Table 10. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with forward longitudinal and inboard transverse positions (PE Experiment 8).

EHP RESULTS FROM EXPERIMENT NUMBER = 8
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 7.5 m Draft, Forward Longitudinal Location, Inboard Transverse Location.

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	172,524.0 FT^2 (16,028.0 M^2)	59.16 FT^2 (5.50 M^2)
DISPLACEMENT	59,392.7 LT (60,343.0 T)	0.37 LT (0.37 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,360.4	2,505.9	2,234.7	1,666.4	0.096	0.324	0.750
12	6.17	5,722.1	4,267.0	3,776.8	2,816.3	0.116	0.389	0.750
14	7.20	8,976.1	6,693.5	5,887.0	4,390.0	0.135	0.454	0.750
16	8.23	13,259.7	9,887.8	8,648.6	6,449.3	0.154	0.519	0.750
18	9.26	19,146.5	14,277.6	12,143.4	9,055.3	0.174	0.584	0.800
20	10.29	27,619.8	20,596.1	16,452.2	12,268.4	0.193	0.649	0.930
22	11.32	38,117.2	28,424.0	21,654.9	16,148.1	0.212	0.713	1.030
24	12.35	50,655.6	37,773.9	27,830.6	20,753.2	0.232	0.778	1.100
26	13.38	68,034.7	50,733.4	35,057.4	26,142.3	0.251	0.843	1.250
28	14.40	96,133.5	71,686.7	43,413.1	32,373.1	0.270	0.908	1.600
30	15.43	139,297.8	103,874.4	52,974.6	39,503.2	0.289	0.973	2.130
32	16.46	190,716.2	142,217.0	63,818.4	47,589.4	0.309	1.038	2.580
34	17.49	247,108.2	184,268.5	76,020.4	56,688.4	0.328	1.103	2.900
36	18.52	313,055.6	233,445.5	89,655.9	66,856.4	0.347	1.167	3.190
38	19.55	390,601.8	291,271.7	104,800.1	78,149.4	0.367	1.232	3.470
40	20.58	481,770.6	359,256.3	121,527.5	90,623.0	0.386	1.297	3.750
42	21.61	579,180.0	431,894.5	139,912.1	104,332.4	0.405	1.362	3.950
44	22.64	690,656.4	515,022.4	160,027.9	119,332.8	0.425	1.427	4.150
45	23.15	750,704.1	559,799.9	170,757.8	127,334.1	0.434	1.459	4.240

Table 11. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with aft longitudinal and inboard transverse positions (PE Experiment 9).

EHP RESULTS FROM EXPERIMENT NUMBER = 9
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 7.5 m Draft, Aft Longitudinal Location, Inboard Transverse Location.

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	172,524.0 FT^2 (16,028.0 M^2)	59.16 FT^2 (5.50 M^2)
DISPLACEMENT	59,392.7 LT (60,343.0 T)	0.37 LT (0.37 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,480.5	2,595.4	2,234.7	1,666.4	0.096	0.324	0.830
12	6.17	5,929.6	4,421.7	3,776.8	2,816.3	0.116	0.389	0.830
14	7.20	9,305.6	6,939.2	5,887.0	4,390.0	0.135	0.454	0.830
16	8.23	13,751.6	10,254.6	8,648.6	6,449.3	0.154	0.519	0.830
18	9.26	19,496.7	14,538.7	12,143.4	9,055.3	0.174	0.584	0.840
20	10.29	27,019.4	20,148.3	16,452.2	12,268.4	0.193	0.649	0.880
22	11.32	39,236.0	29,258.3	21,654.9	16,148.1	0.212	0.713	1.100
24	12.35	56,258.1	41,951.6	27,830.6	20,753.2	0.232	0.778	1.370
26	13.38	70,409.0	52,504.0	35,057.4	26,142.3	0.251	0.843	1.340
28	14.40	93,497.4	69,721.0	43,413.1	32,373.1	0.270	0.908	1.520
30	15.43	134,434.6	100,247.8	52,974.6	39,503.2	0.289	0.973	2.010
32	16.46	192,683.6	143,684.1	63,818.4	47,589.4	0.309	1.038	2.620
34	17.49	255,367.6	190,427.6	76,020.4	56,688.4	0.328	1.103	3.040
36	18.52	319,358.4	238,145.5	89,655.9	66,856.4	0.347	1.167	3.280
38	19.55	384,836.3	286,972.4	104,800.1	78,149.4	0.367	1.232	3.400
40	20.58	465,439.6	347,078.2	121,527.5	90,623.0	0.386	1.297	3.580
42	21.61	556,938.6	415,309.0	139,912.1	104,332.4	0.405	1.362	3.750
44	22.64	658,690.8	491,185.7	160,027.9	119,332.8	0.425	1.427	3.900
45	23.15	715,141.3	533,280.8	170,757.8	127,334.1	0.434	1.459	3.980

Table 12. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with aft longitudinal and middle transverse positions (PE Experiment 10).

EHP RESULTS FROM EXPERIMENT NUMBER = 10
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 7.5 m Draft, Aft Longitudinal Location, Middle Transverse Location.

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	172,524.0 FT^2 (16,028.0 M^2)	59.16 FT^2 (5.50 M^2)
DISPLACEMENT	59,392.7 LT (60,343.0 T)	0.37 LT (0.37 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,360.4	2,505.9	2,234.7	1,666.4	0.096	0.324	0.750
12	6.17	5,722.1	4,267.0	3,776.8	2,816.3	0.116	0.389	0.750
14	7.20	8,976.1	6,693.5	5,887.0	4,390.0	0.135	0.454	0.750
16	8.23	13,259.7	9,887.8	8,648.6	6,449.3	0.154	0.519	0.750
18	9.26	18,883.9	14,081.7	12,143.4	9,055.3	0.174	0.584	0.770
20	10.29	26,298.9	19,611.1	16,452.2	12,268.4	0.193	0.649	0.820
22	11.32	39,236.0	29,258.3	21,654.9	16,148.1	0.212	0.713	1.100
24	12.35	53,456.8	39,862.7	27,830.6	20,753.2	0.232	0.778	1.230
26	13.38	65,396.5	48,766.1	35,057.4	26,142.3	0.251	0.843	1.150
28	14.40	86,248.4	64,315.4	43,413.1	32,373.1	0.270	0.908	1.300
30	15.43	134,434.6	100,247.8	52,974.6	39,503.2	0.289	0.973	2.010
32	16.46	201,045.1	149,919.3	63,818.4	47,589.4	0.309	1.038	2.790
34	17.49	264,806.9	197,466.5	76,020.4	56,688.4	0.328	1.103	3.200
36	18.52	310,254.3	231,356.6	89,655.9	66,856.4	0.347	1.167	3.150
38	19.55	357,656.3	266,704.3	104,800.1	78,149.4	0.367	1.232	3.070
40	20.58	420,289.1	313,409.5	121,527.5	90,623.0	0.386	1.297	3.110
42	21.61	499,110.9	372,186.9	139,912.1	104,332.4	0.405	1.362	3.230
44	22.64	594,759.6	443,512.2	160,027.9	119,332.8	0.425	1.427	3.400
45	23.15	645,383.7	481,262.5	170,757.8	127,334.1	0.434	1.459	3.470

Table 13. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 9.5 m drafts with middle longitudinal and inboard transverse positions (PE Experiment 11).

EHP RESULTS FROM EXPERIMENT NUMBER = 11
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 9.5 m Draft, Middle Longitudinal Location, Inboard Transverse Location.

	SHIP	MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	186,258.7 FT^2 (17,304.0 M^2)	63.87 FT^2 (5.93 M^2)
DISPLACEMENT	61,011.8 LT (61,987.0 T)	0.38 LT (0.38 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,709.0	2,765.8	2,412.6	1,799.1	0.096	0.324	0.800
12	6.17	6,317.6	4,711.1	4,077.4	3,040.5	0.116	0.389	0.800
14	7.20	9,913.0	7,392.1	6,355.7	4,739.4	0.135	0.454	0.800
16	8.23	14,647.2	10,922.4	9,337.1	6,962.7	0.154	0.519	0.800
18	9.26	20,670.7	15,414.2	13,110.1	9,776.2	0.174	0.584	0.800
20	10.29	28,133.2	20,978.9	17,761.9	13,245.1	0.193	0.649	0.800
22	11.32	40,634.0	30,300.8	23,378.8	17,433.6	0.212	0.713	1.000
24	12.35	53,568.1	39,945.7	30,046.1	22,405.4	0.232	0.778	1.050
26	13.38	65,333.4	48,719.1	37,848.3	28,223.4	0.251	0.843	0.965
28	14.40	82,086.7	61,212.1	46,869.1	34,950.3	0.270	0.908	0.990
30	15.43	104,664.5	78,048.3	57,191.8	42,647.9	0.289	0.973	1.085
32	16.46	126,778.6	94,538.8	68,898.9	51,377.9	0.309	1.038	1.090
34	17.49	152,133.7	113,446.1	82,072.2	61,201.2	0.328	1.103	1.100
36	18.52	189,032.9	140,961.8	96,793.2	72,178.7	0.347	1.167	1.220
38	19.55	255,415.7	190,463.4	113,143.0	84,370.8	0.367	1.232	1.600
40	20.58	348,997.9	260,247.7	131,202.0	97,837.3	0.386	1.297	2.100
42	21.61	471,610.4	351,679.8	151,050.2	112,638.1	0.405	1.362	2.670
44	22.64	625,542.2	466,466.8	172,767.3	128,832.6	0.425	1.427	3.280
45	23.15	704,144.7	525,080.6	184,351.5	137,470.9	0.434	1.459	3.520

Table 14. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 12.0 m draft, side hulls at 10.0 m drafts with middle longitudinal and inboard transverse positions (PE Experiment 12).

EHP RESULTS FROM EXPERIMENT NUMBER = 12
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 12.0 m Draft. Side Hulls @ 10.0 m Draft, Middle Longitudinal Location, Inboard Transverse Location.

	SHIP	MODEL
LENGTH	984.02 FT (299.93 M)	18.22 FT (5.55 M)
WETTED SURFACE	193,664.3 FT^2 (17,992.0 M^2)	66.41 FT^2 (6.17 M^2)
DISPLACEMENT	64,271.7 LT (65,300.0 T)	0.40 LT (0.40 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,930.2	2,930.7	2,498.0	1,862.7	0.095	0.319	0.850
12	6.17	6,696.8	4,993.8	4,222.0	3,148.3	0.114	0.383	0.850
14	7.20	10,511.2	7,838.2	6,581.2	4,907.6	0.133	0.446	0.850
16	8.23	15,535.0	11,584.5	9,668.8	7,210.0	0.152	0.510	0.850
18	9.26	21,928.7	16,352.3	13,576.2	10,123.8	0.171	0.574	0.850
20	10.29	29,851.4	22,260.2	18,393.9	13,716.3	0.190	0.638	0.850
22	11.32	43,946.4	32,770.8	24,211.1	18,054.2	0.209	0.701	1.100
24	12.35	57,669.8	43,004.4	31,116.4	23,203.5	0.228	0.765	1.140
26	13.38	69,107.7	51,533.6	39,197.2	29,229.4	0.247	0.829	1.010
28	14.40	86,637.6	64,605.6	48,540.4	36,196.6	0.266	0.893	1.030
30	15.43	110,866.8	82,673.3	59,232.1	44,169.4	0.285	0.956	1.135
32	16.46	135,127.4	100,764.5	71,357.8	53,211.5	0.304	1.020	1.155
34	17.49	161,822.8	120,671.2	85,002.4	63,386.3	0.323	1.084	1.160
36	18.52	201,660.0	150,377.8	100,250.4	74,756.7	0.341	1.148	1.290
38	19.55	266,963.4	199,074.6	117,185.5	87,385.2	0.360	1.211	1.620
40	20.58	373,668.5	278,644.6	135,891.2	101,334.1	0.379	1.275	2.205
42	21.61	507,231.4	378,242.4	156,450.5	116,665.1	0.398	1.339	2.810
44	22.64	664,074.1	495,200.0	178,945.8	133,439.9	0.417	1.403	3.380
45	23.15	748,292.5	558,001.6	190,945.2	142,387.8	0.427	1.435	3.630

Table 15. Predicted effective power for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 11.5 m drafts with middle longitudinal and inboard transverse positions (PE Experiment 13).

EHP RESULTS FROM EXPERIMENT NUMBER = 13
DTRC MODEL NUMBER = 5651
MODEL CONDITION = HALSS: Center Hull @ 11.5 m Draft. Side Hulls @ 11.5 m Draft, Middle Longitudinal Location, Inboard Transverse Location.

SHIP		MODEL
LENGTH	950.83 FT (289.8 M)	17.61 FT (5.367 M)
WETTED SURFACE	200,746.9 FT^2 (18,650.0 M^2)	68.85 FT^2 (6.40 M^2)
DISPLACEMENT	62,686.0 LT (63,689.0 T)	0.39 LT (0.39 T)
RHO	1.9905 (31.885 N S^2/M^4)	1.9367 (31.023 N S^2/M^4)
NU (E+5)	1.2816 (0.11906 M^2/SEC)	1.0836 (0.10067 M^2/SEC)

LINEAR RATIO 54.000
ITTC FRICTION LINE
CORRELATION ALLOWANCE (CA) 0.00000

Vs		PE		FRICTIONAL POWER		Fn	V-L	1000 * Cr
KNOTS	m/s	HP	Kw	HP	Kw			
10	5.14	3,875.2	2,889.7	2,600.2	1,939.0	0.096	0.324	0.730
12	6.17	6,597.7	4,919.9	4,394.6	3,277.0	0.116	0.389	0.730
14	7.20	10,348.6	7,716.9	6,850.0	5,108.1	0.135	0.454	0.730
16	8.23	15,285.6	11,398.5	10,063.3	7,504.2	0.154	0.519	0.730
18	9.26	21,565.4	16,081.3	14,129.8	10,536.6	0.174	0.584	0.730
20	10.29	29,622.7	22,089.6	19,143.4	14,275.2	0.193	0.649	0.750
22	11.32	42,864.5	31,964.1	25,197.2	18,789.5	0.212	0.713	0.950
24	12.35	56,527.2	42,152.3	32,383.0	24,148.0	0.232	0.778	1.000
26	13.38	68,419.5	51,020.4	40,792.0	30,418.6	0.251	0.843	0.900
28	14.40	85,787.4	63,971.6	50,514.5	37,668.6	0.270	0.908	0.920
30	15.43	111,154.5	82,887.9	61,640.0	45,964.9	0.289	0.973	1.050
32	16.46	136,639.1	101,891.8	74,257.6	55,373.9	0.309	1.038	1.090
34	17.49	163,966.2	122,269.6	88,455.5	65,961.3	0.328	1.103	1.100
36	18.52	203,735.3	151,925.4	104,321.5	77,792.5	0.347	1.167	1.220
38	19.55	275,281.1	205,277.1	121,943.0	90,932.9	0.367	1.232	1.600
40	20.58	376,141.9	280,489.0	141,406.5	105,446.8	0.386	1.297	2.100
42	21.61	508,290.9	379,032.4	162,798.4	121,398.8	0.405	1.362	2.670
44	22.64	674,195.0	502,747.1	186,204.6	138,852.8	0.425	1.427	3.280
45	23.15	758,910.9	565,919.8	198,689.8	148,162.9	0.434	1.459	3.520

Table 16. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and inboard transverse positions (Experiment 5).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
10	0.14	0.04	0.28	0.09	0.01
12	0.21	0.07	0.39	0.12	0.01
14	0.29	0.09	0.48	0.15	0.01
15	0.36	0.11	0.57	0.17	0.01
16	0.37	0.11	0.54	0.16	0.01
18	0.50	0.15	0.69	0.21	0.01
20	0.67	0.20	0.72	0.22	0.00
22	0.85	0.26	0.92	0.28	0.00
24	1.07	0.32	1.15	0.35	0.00
25	1.22	0.37	1.32	0.40	0.01
26	1.27	0.39	1.34	0.41	0.00
28	1.45	0.44	1.59	0.48	0.01
30	1.58	0.48	1.88	0.57	0.02
32	1.77	0.54	2.15	0.65	0.02
34	2.09	0.64	2.51	0.76	0.02
35	2.16	0.66	2.82	0.86	0.04
36	2.06	0.63	3.14	0.96	0.06
38	1.59	0.49	4.45	1.35	0.16
40	0.67	0.20	6.29	1.92	0.31
42	-0.90	-0.27	8.40	2.56	0.51
44	-3.12	-0.95	11.04	3.36	0.78
45	-4.05	-1.23	12.05	3.67	0.89

Table 17. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and transverse positions (Experiment 6).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
10	0.14	0.04	0.19	0.06	0.00
12	0.23	0.07	0.32	0.10	0.01
14	0.28	0.08	0.40	0.12	0.01
15	0.26	0.08	0.49	0.15	0.01
16	0.38	0.11	0.55	0.17	0.01
18	0.47	0.14	0.60	0.18	0.01
20	0.78	0.24	0.82	0.25	0.00
22	0.91	0.28	0.90	0.27	0.00
24	1.02	0.31	1.12	0.34	0.01
25	1.17	0.36	1.17	0.36	0.00
26	1.26	0.38	1.17	0.36	-0.01
26	1.30	0.40	1.14	0.35	-0.01
28	1.51	0.46	1.48	0.45	0.00
30	1.57	0.48	1.73	0.53	0.01
32	1.80	0.55	1.95	0.60	0.01
34	2.22	0.68	2.37	0.72	0.01
35	2.22	0.68	2.62	0.80	0.02
36	2.09	0.64	2.95	0.90	0.05
38	1.54	0.47	4.65	1.42	0.17
40	0.26	0.08	6.59	2.01	0.35
42	-1.49	-0.45	8.90	2.71	0.57
44	-3.58	-1.09	11.46	3.49	0.83
45	-4.66	-1.42	12.49	3.81	0.95

Table 18. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with middle longitudinal and outboard transverse positions (Experiment 7).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
10	0.15	0.05	0.23	0.07	0.00
12	0.23	0.07	0.30	0.09	0.00
14	0.25	0.08	0.40	0.12	0.01
15	0.30	0.09	0.41	0.13	0.01
16	0.31	0.09	0.46	0.14	0.01
18	0.53	0.16	0.63	0.19	0.01
20	0.73	0.22	0.75	0.23	0.00
22	0.88	0.27	0.86	0.26	0.00
24	1.02	0.31	0.91	0.28	-0.01
25	1.23	0.37	1.08	0.33	-0.01
26	1.30	0.40	1.20	0.36	-0.01
28	1.39	0.42	1.37	0.42	0.00
30	1.69	0.51	1.67	0.51	0.00
32	1.72	0.52	1.94	0.59	0.01
34	2.07	0.63	2.58	0.79	0.03
35	2.00	0.61	2.77	0.84	0.04
36	1.87	0.57	3.35	1.02	0.08
38	1.14	0.35	4.83	1.47	0.20
40	-0.03	-0.01	6.84	2.08	0.38
42	-1.41	-0.43	8.84	2.69	0.57
44	-3.01	-0.92	10.75	3.28	0.76
45	-3.98	-1.21	11.77	3.59	0.87

Table 19. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, sid(hulls at 7.5 m drafts with forward longitudinal and inboa transverse positions (Experiment 8).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
10	0.27	0.08	0.15	0.05	-0.01
12	0.37	0.11	0.18	0.05	-0.01
14	0.57	0.17	0.22	0.07	-0.02
15	0.62	0.19	0.23	0.07	-0.02
16	0.69	0.21	0.23	0.07	-0.03
18	0.93	0.28	0.28	0.08	-0.04
20	1.30	0.39	0.39	0.12	-0.05
22	1.51	0.46	0.41	0.12	-0.06
24	1.87	0.57	0.49	0.15	-0.08
25	2.09	0.64	0.58	0.18	-0.08
26	2.35	0.72	0.67	0.20	-0.09
28	2.61	0.79	0.86	0.26	-0.10
30	2.96	0.90	1.23	0.38	-0.10
32	3.67	1.12	1.58	0.48	-0.12
34	4.60	1.40	1.52	0.46	-0.17
35	5.10	1.55	1.57	0.48	-0.20
36	5.42	1.65	1.71	0.52	-0.21
38	6.10	1.86	2.31	0.71	-0.21
40	5.76	1.76	3.77	1.15	-0.11
42	5.33	1.63	5.59	1.70	0.01
44	4.27	1.30	7.66	2.34	0.19
45	3.04	0.93	8.86	2.70	0.32

Table 20. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with aft longitudinal and inboard transverse positions (Experiment 9).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
10	0.07	0.02	0.19	0.06	0.01
12	0.02	0.01	0.24	0.07	0.01
14	0.02	0.01	0.41	0.13	0.02
15	0.17	0.05	0.54	0.16	0.02
16	0.23	0.07	0.65	0.20	0.02
18	0.28	0.08	0.76	0.23	0.03
20	0.46	0.14	0.95	0.29	0.03
22	0.54	0.16	1.07	0.33	0.03
24	0.55	0.17	1.53	0.47	0.05
25	0.66	0.20	1.73	0.53	0.06
26	0.64	0.19	1.83	0.56	0.07
28	0.65	0.20	2.32	0.71	0.09
30	0.29	0.09	3.19	0.97	0.16
32	-0.23	-0.07	4.17	1.27	0.24
34	-0.85	-0.26	5.03	1.53	0.33
35	-1.13	-0.35	5.61	1.71	0.37
36	-1.52	-0.46	6.22	1.90	0.43
38	-2.46	-0.75	7.48	2.28	0.55
40	-3.65	-1.11	9.08	2.77	0.70
42	-5.15	-1.57	10.90	3.32	0.89
44	-6.86	-2.09	12.83	3.91	1.09
45	-7.58	-2.31	13.56	4.13	1.17

Table 21. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 7.5 m drafts with aft longitudinal and middle transverse positions (Experiment 10).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
10	0.10	0.03	0.20	0.06	0.01
12	0.12	0.04	0.36	0.11	0.01
14	0.14	0.04	0.44	0.14	0.02
15	0.22	0.07	0.49	0.15	0.02
17	0.36	0.11	0.65	0.20	0.02
18	0.41	0.12	0.65	0.20	0.01
20	0.48	0.15	0.83	0.25	0.02
22	0.59	0.18	1.02	0.31	0.02
24	0.73	0.22	1.44	0.44	0.04
25	0.78	0.24	1.56	0.47	0.04
26	0.81	0.25	1.73	0.53	0.05
28	0.73	0.22	2.09	0.64	0.08
30	0.40	0.12	2.85	0.87	0.14
32	-0.19	-0.06	3.94	1.20	0.23
34	-0.79	-0.24	4.99	1.52	0.32
35	-1.18	-0.36	5.40	1.65	0.36
36	-1.35	-0.41	5.82	1.77	0.40
38	-2.00	-0.61	6.91	2.10	0.49
40	-2.80	-0.85	8.15	2.49	0.61
42	-4.07	-1.24	9.74	2.97	0.76
44	-5.35	-1.63	11.22	3.42	0.92
45	-6.12	-1.87	11.99	3.66	1.00

Table 22. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 9.5 m drafts with middle longitudinal and inboard transverse positions (Experiment 11).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
18	0.55	0.17	0.52	0.16	0.00
20	0.65	0.20	0.57	0.17	0.00
21	1.02	0.31	0.98	0.30	0.00
22	0.84	0.25	0.75	0.23	-0.01
24	1.16	0.35	1.07	0.33	-0.01
26	1.39	0.42	1.37	0.42	0.00
28	1.50	0.46	1.37	0.42	-0.01
30	1.74	0.53	1.93	0.59	0.01
32	1.74	0.53	2.04	0.62	0.02
34	2.14	0.65	2.61	0.80	0.03
36	2.03	0.62	3.11	0.95	0.06
38	1.46	0.44	4.30	1.31	0.16
40	0.45	0.14	6.48	1.98	0.33
42	-1.36	-0.41	8.66	2.64	0.55
44	-3.13	-0.95	11.27	3.44	0.80

Table 23. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twir skegs and bow bulb, with center hull at 12.0 m draft, sid hulls at 10.0 m drafts with middle longitudinal and inbo: transverse positions (Experiment 12).

Notes: - Static Drafts @ FP & AP = 39.4 ft (12 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
18	0.69	0.21	0.42	0.13	-0.01
20	0.90	0.27	0.53	0.16	-0.02
22	1.07	0.33	0.77	0.23	-0.02
24	1.13	0.34	0.82	0.25	-0.02
26	1.53	0.47	1.15	0.35	-0.02
28	1.70	0.52	1.23	0.37	-0.03
30	1.84	0.56	1.70	0.52	-0.01
32	2.03	0.62	2.01	0.61	0.00
35	2.37	0.72	2.47	0.75	0.01
36	2.36	0.72	2.94	0.90	0.03
38	1.91	0.58	4.11	1.25	0.12
40	0.80	0.24	5.89	1.80	0.28
42	-0.96	-0.29	8.40	2.56	0.52
44	-2.84	-0.87	10.71	3.27	0.75

Table 24. Predicted dynamic sinkage and pitch for the HALSS trimaran, as represented by Model 5651, fitted with twin skegs and bow bulb, with center hull at 11.5 m draft, side hulls at 11.5 m drafts with middle longitudinal and inboard transverse positions (Experiment 13).

Notes: - Static Drafts @ FP & AP = 37.7 ft (11.5 m)
- Positive (+) Sinkage Down

Vs (knots)	Sinkage FP (ft)	Sinkage FP (m)	Sinkage AP (ft)	Sinkage AP (m)	Pitch Angle (°)
16	0.38	0.12	0.50	0.15	0.01
18	0.57	0.17	0.66	0.20	0.01
20	0.71	0.22	0.75	0.23	0.00
22	0.88	0.27	0.91	0.28	0.00
24	1.08	0.33	1.21	0.37	0.01
26	1.32	0.40	1.36	0.42	0.00
28	1.50	0.46	1.44	0.44	0.00
30	1.64	0.50	1.99	0.61	0.02
32	1.86	0.57	2.35	0.72	0.03
34	2.05	0.62	2.73	0.83	0.04
36	2.02	0.62	3.39	1.03	0.08
38	1.37	0.42	4.65	1.42	0.18
40	0.22	0.07	6.67	2.03	0.36
42	-1.59	-0.49	9.08	2.77	0.59
44	-3.55	-1.08	11.54	3.52	0.83

REFERENCES

[1] "Proposed Design Power Margin Policy and Ship/Model Correlation Allowance Policy for New U.S. Navy Surface Ship Designs - Update No. 1", NAVSEA Report 55W3-82-15, (Nov. 1982).

[2] Grant, J. W., and C. J. Wilson, "Design Practices for Powering Predictions", DTNSRDC/SPD-0693-01, (Oct. 1976).

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APPENDIX A:

LDV Propeller Nominal Wake Surveys

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FIGURES OF APPENDIX A

Page

A1. Fiber-optic probes and strut A10

A2. LDV strut and fiber-optic probes A10

A3. LDV Strut behind model A11

A4. Measured velocities, 30 knots, with side hulls A12

A5. Measured velocities, 30 knots, no side hulls A12

A6. Velocities at starboard shaft, 30 knots, $r/R = 0.50$ A13

A7. Velocities at starboard shaft, 30 knots, $r/R = 0.70$ A13

A8. Velocities at starboard shaft, 30 knots, $r/R = 1.00$ A14

NOTATION

L Length of hull at waterline

q Root-mean-square (RMS) fluctuation of velocity, TKE = $\rho q^2/2$, normalized by U_∞

s Direction along the shaft (+ downstream)

U Magnitude of total velocity

U_1 First measured component of velocity, in direction of model axis

U_2 Second measured component of velocity

U_3 Third measured component of velocity

U_r Velocity in radial direction from shaft, normalized by U_∞ (+ out)

U_s Velocity in shaft direction, normalized by U_∞ (+ aft)

U_t Velocity in tangential direction from shaft, normalized by U_∞ (+ CCW looking upstream)

U_x Velocity in direction of model travel, normalized by U_∞ (+ downstream)

Uy Velocity in horizontal direction, perpendicular to model travel, normalized by U∞ (+ starboard)

U_z Velocity in vertical direction, normalized by U_∞ (+ up)

U_∞ Model speed

x Coordinate in horizontal plane, in direction of model travel, from bow waterline, normalized by L

y Coordinate in horizontal plane, perpendicular to x, from centerline, normalized by L (+ starboard)

z Coordinate vertical direction, from baseline, normalized by L (+ up)

θ_2 Angle between measured velocity component 2 and y axis

θ_3 Angle between measured velocity component 3 and y axis

INTRODUCTION

In order to design a propeller for this hull, the nominal wake at the starboard propeller plane was measured using Laser Doppler Velocimetry (LDV). The model conditions and the measurement apparatus will be described in the next sections.

EXPERIMENTAL APPARATUS

Probes and Strut

The LDV system consisted of two TSI Model 9832 fiber-optic probes attached to each other on a streamlined strut as shown in Figures A1 through A3. The probes were mounted rigidly together on the strut in order to keep the measurement volumes aligned. In order to measure at different points in the flow, the probes could be translated in a plane perpendicular to the model axis as a unit.

The left probe in Figure A1 used the green (514.5 nm) and blue (488 nm) beams of an argon-ion laser to measure two components of velocity, U_1 and U_2, and the lower-right probe used the violet (476.5 nm) beams of the laser to measure a third component, U_3. The probes are oriented with their axes parallel to the flow direction (the x axis), and have prisms at the front lens to deflect the beams by 90°. The probes have 50 mm beam spacing and 500 mm focal length (air) lenses. Each probe has an elliptical probe volume with a major axis of 2.0 mm and both minor axes of 0.01 mm. The probe volumes are approximately 620 mm from the probe centerlines in water.

The fringe spacings for the green, blue, and violet beams were 5.233 μm, 4.903 μm, and 4.868 μm, respectively. The probes were oriented so that the green channel measured the axial component of velocity, U_1, the blue channel measured a velocity component U_2 perpendicular to the x axis and at 39.13° to the y axis, and the violet channel measured a velocity component U_3 perpendicular to the x axis and at 30.44° to the y axis. These angles were designed to give maximum access to the flowfield while keeping the strut and probes as far from the model as possible.

The strut consisted of 2 inch by 4 inch aluminum extrusions bolted together as shown in Figure A2. On the leading and trailing edges of the strut, 4 inch long double-circular-arc fairings of renshape were attached. These fairings had interior passages to pass the probe cables. Two streamlined braces were attached laterally to the main strut, and one streamlined brace was attached forward of the main strut to provide extra rigidity.

Signal Processing

Doppler signals were analyzed with a TSI Model FSA 3500 signal processor. The processor performs a 256 sample autocorrelation on each doppler burst at a dynamically optimized sampling rate, allowing the measurement of velocity even when the signal-to-noise ratio is low. In order to maximize data rate, the processors were operated in the random mode.

Seeding

The flow about the hull was seeded with 1500 grit silicon carbide powder of mean diameter of 1 to 2 μm. The powder was mixed into a slurry with water and injected through seven 0.1 inch diameter taps in the hull at $x/L = 0.2$.

Traverse

The strut assembly was attached to the carriage through a two component, computer controlled, traverse. The traverse sat on the carriage, above the water level. The traverse was powered by two stepping motors attached to 5 threads per inch lead screws. Position was determined by rotary encoders mounted to the stepping motors.

The traverse could move the probes in the y and z directions. Positioning in the x direction was achieved by manually moving the hull on the center rail of the carriage. The range of movement in the y direction was approximately 19 inches, and the in the z direction the measurement volume could be positioned to approximately 20 inches below the water surface.

EXPERIMENTAL PROCEDURE

At each point in the flow, measurements were obtained for 5 seconds. In this time between 200 and 8000 velocity realizations were recorded for each velocity components. Data rate varied from point to point due to the density of seed in the flow. Data rate was approximately equal on each channel. During each carriage pass, the probe assembly was moved to different positions under computer control. Approximately 10 points could be obtained in each pass.

Position of the measurement location was determined by aligning to a reference mark on the hull. At each axial location the hull was positioned fore and aft to bring the reference mark and the plane of the laser beams into coincidence, and then adjusted for the proper dynamic sinkage and trim for the test speed. Once the hull was locked onto the rail, the traverse was then moved in the *y* and *z* directions to bring the beam crossing onto the mark. A circular grid of 289 points centered on the shaft was measured to the propeller radius.

MEASUREMENT CONDITIONS

Measurements of the nominal wakes were made at 4.08 knots, corresponding to a full-scale speed of 30 knots. The model was fixed at the correct dynamic sinkage and trim for this condition. For 15 knots the model pitch was -0.13° (bow down), and at 30 knots the model was pitched 1.36° bow up. The model had no dummy hubs or shafts in place of the propellers so that unobstructed measurements could be made at the nominal propeller plane.

DATA REDUCTION

Coordinate Transformations: Measured to World

Three components of velocity, U_1, U_2, and U_3, were measured with the present system, but the components were not aligned with the *x*, *y*, and *z* world axes, nor were they perpendicular, as illustrated in Figure A1. The relationship between the measured components and the world axes are defined by the angles θ_2 and θ_3. These angles are –39.13° and 50.87°, respectively. The measured velocities are transformed to the world coordinates by;

$$U_x = U_1 \tag{A1}$$

$$U_y = \frac{U_2 \sin\theta_3 - U_3 \sin\theta_2}{\sin(\theta_3 - \theta_2)} \tag{A2}$$

$$U_z = \frac{U_2 \cos\theta_3 - U_3 \cos\theta_2}{\sin(\theta_3 - \theta_2)} \tag{A3}$$

Strut Interference Corrections

Although the measurement volume was some distance from the probes and strut, there was still some disturbance of the measured flow by the hardware. This disturbance is the result of flow being deflected by the probes and strut, and from waves generated by the probes and strut. Due to the free surface, the effect is a function both of carriage speed and measurement depth. The disturbance was quantified by measuring the water velocity with no model attached. If there is no disturbance of the flow, U_1 should measure the carriage speed, and U_2 and U_3 should be zero. A correction to bring the no-model velocities to their ideal values was calculated. At 4.08 knots the corrections are;

$$U_{x\ corrected} = \frac{U_{x\ raw}}{(0.976 - 0.00067z)} \tag{A4}$$

$$U_{y\ corrected} = U_{y\ raw} + U_{x\ corrected} \cdot 0.0155 \tag{A5}$$

$$U_{z\ corrected} = U_{z\ raw} + U_{x\ corrected} \cdot 0.005 \tag{A6}$$

$$U_{z\ corrected} = U_{z\ raw} + U_{x\ corrected} (0.019 - z \cdot 0.000467) \tag{A7}$$

where z is the distance below the undisturbed water surface, in inches, and the velocities are normalized by model speed. The resultant corrections are small, generally less than 2% of model speed. These corrections are applied to all measurements presented here.

MEASUREMENT UNCERTAINTY

The primary source of measurement uncertainty is flow fluctuations, which occur on time scales and are significant in comparison to the necessarily finite measurement time. These long scale fluctuations result in an uncertainty in the measured velocity of approximately $0.007U_\infty$ in the shaft wake region, and approximately $0.005U_\infty$ in the rest of the flow field. Angular uncertainty is approximately 0.5°.

RESULTS

Velocity Fields

The measured velocities at the starboard shaft at 30 knots with side hulls on are shown in Figure A4. Plotted for reference in this figure are two black circles which represent the hub and propeller tip diameters. The color contours represent the magnitude of the velocity in the axial (shaft) direction, U_x, and the vectors represent the velocities perpendicular to U_x. The measurement locations are at the tail of each vector.

The nominal wake shows a slight radial gradient of U_x, with a strong, diagonally oriented to the skeg wake. The axial velocity near the center of the disc is very low due to the truncation of the skeg where the propeller would normally be attached. The secondary flow is primarily upward and slightly inboard due to the rise of the hull. In the skeg wake, however, the secondary flow sweeps in toward the shaft.

The measured velocities at the starboard shaft at 30 knots with no side hulls on are shown in Figure A5. The velocities are nearly identical to those with the side hulls in place. With no side hulls in place, the secondary velocities show a slightly more upward flow, with the resultant skeg wake at the center of the disc more pronounced above the centerline.

Circumferential Cuts

The velocities at 50%, 70%, and 100% of propeller radius are shown in Figures A6 to A8. These figures are for the case of the side hulls in place, since the no-side-hulls case is nearly identical. In these figures, zero degrees is directly above the shaft, and the angle is positive to the inboard.

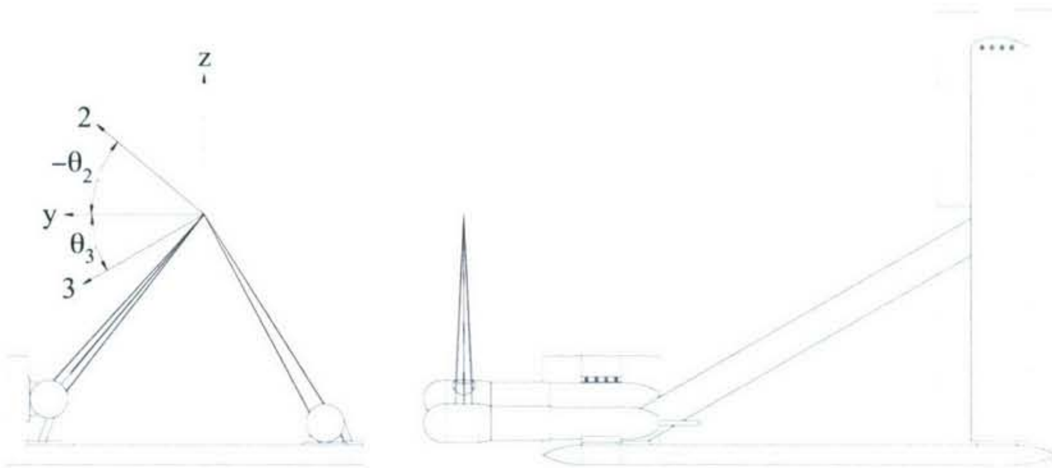

Figure A1. Fiber-optic probes and strut.

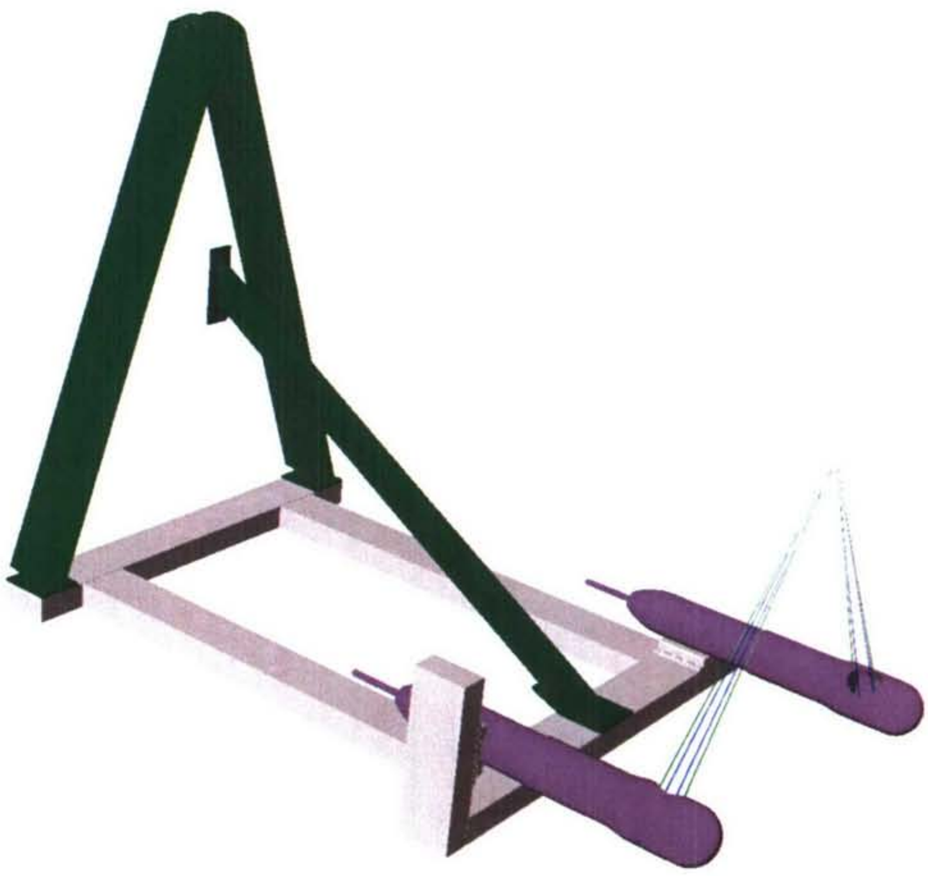

Figure A2. LDV strut and fiber-optic probes.

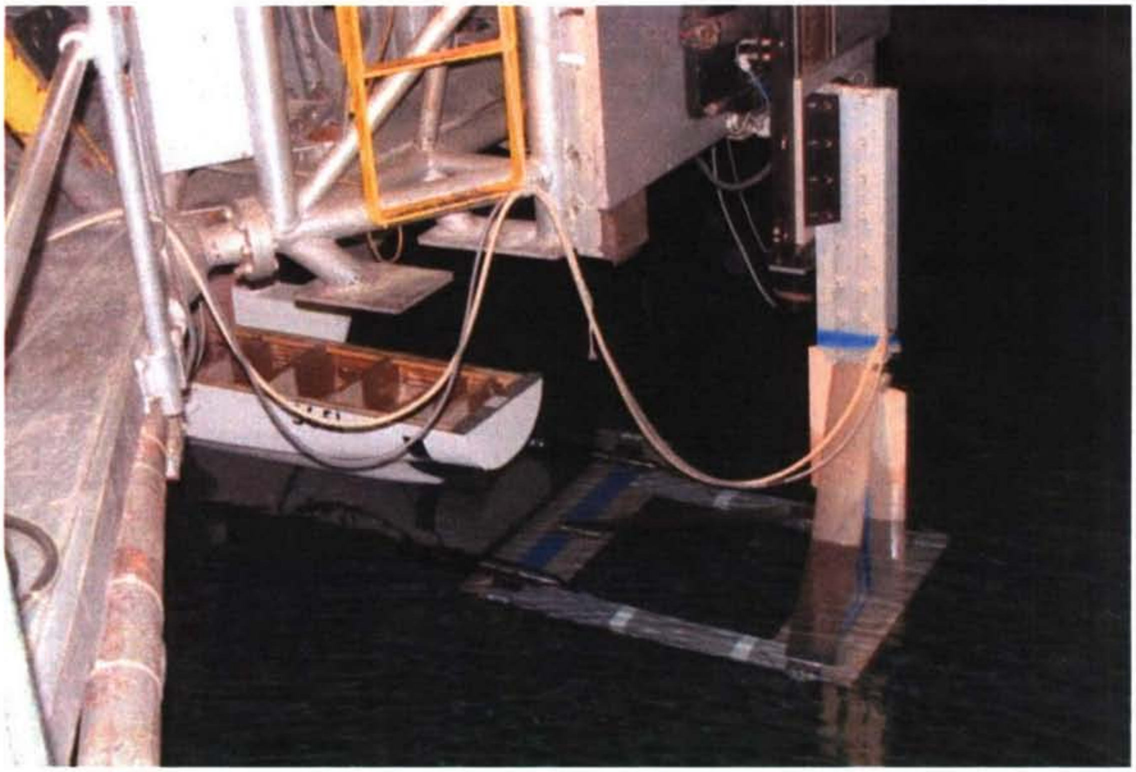

Figure A3. LDV Strut behind model.

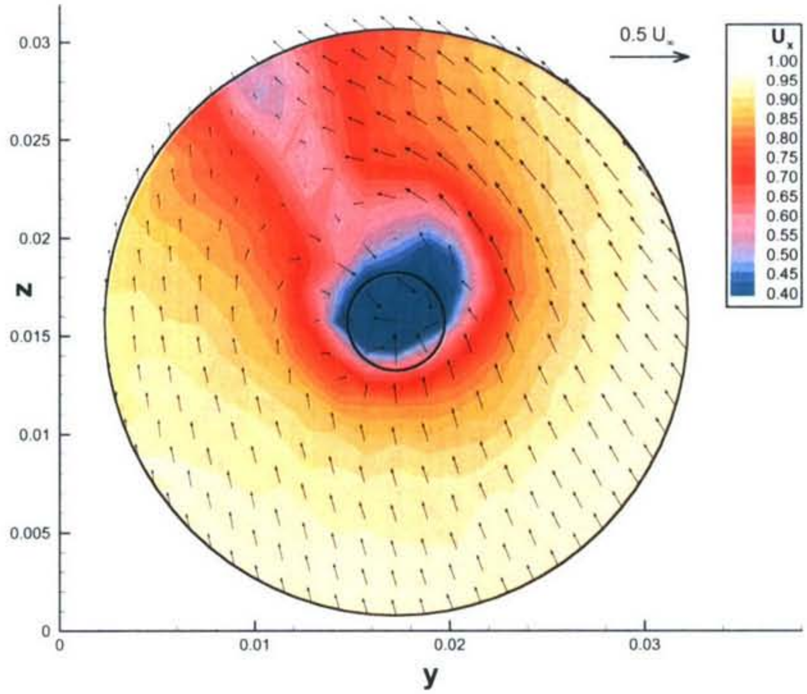

Figure A4. Measured velocities, 30 knots, with side hulls.

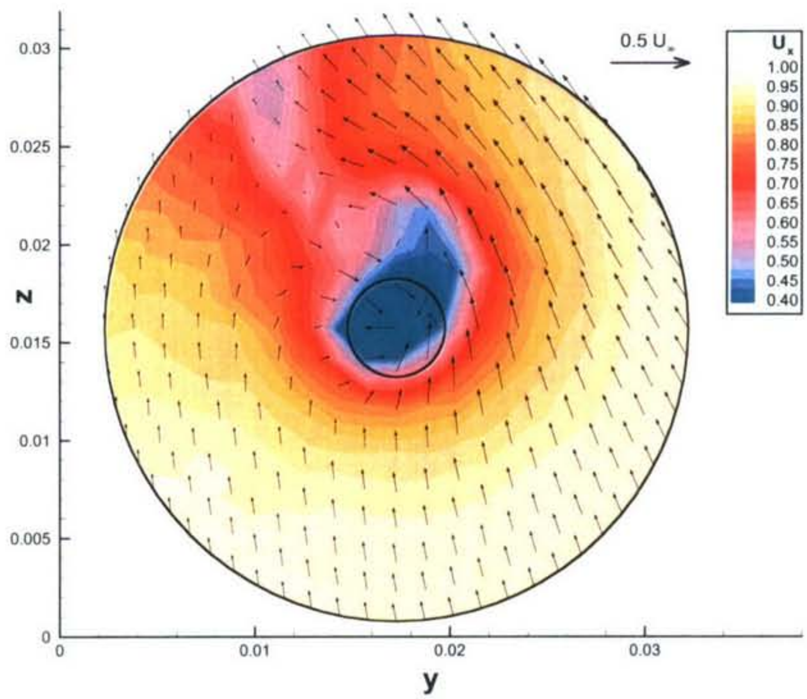

Figure A5. Measured velocities, 30 knots, no side hulls.

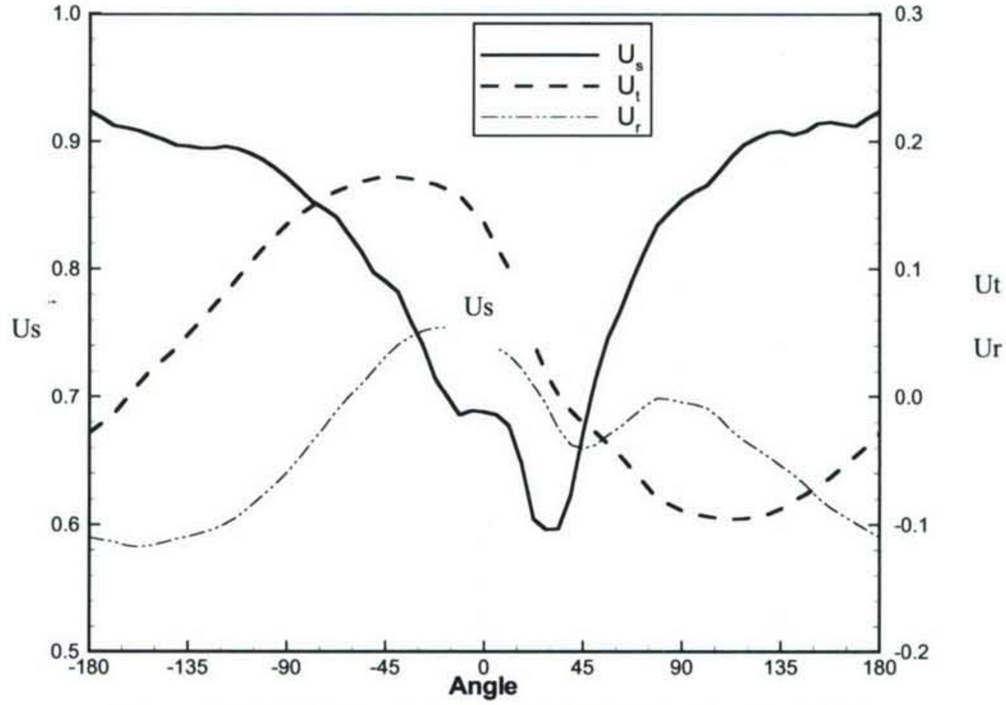

Figure A6. Velocities at starboard shaft, 30 knots, $r/R = 0.50$.

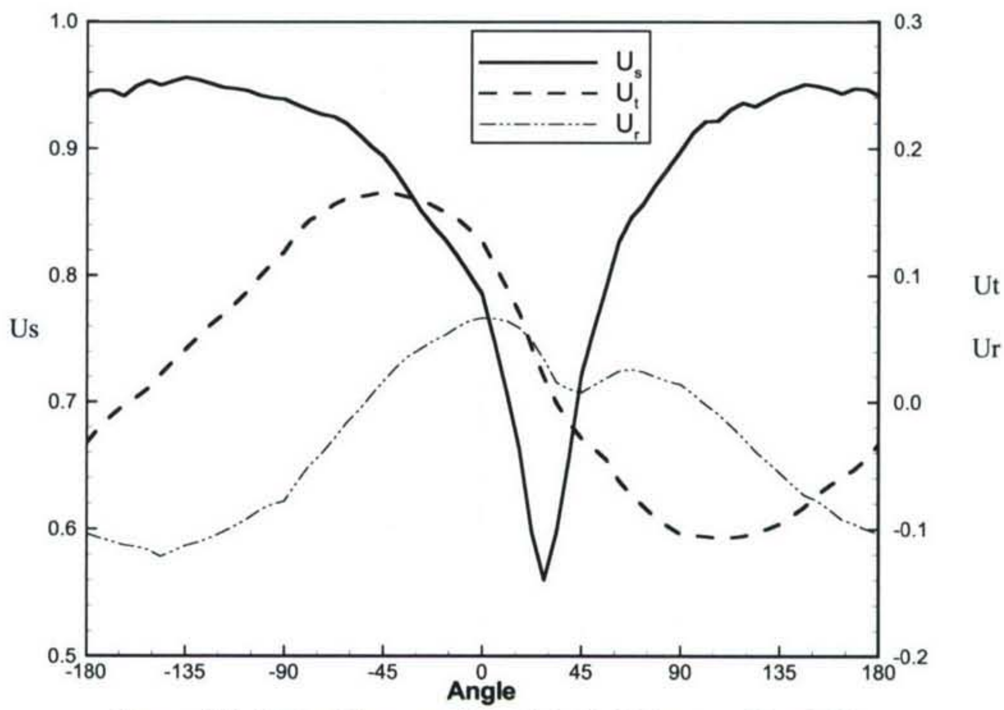

Figure A7. Velocities at starboard shaft, 30 knots, $r/R = 0.70$.

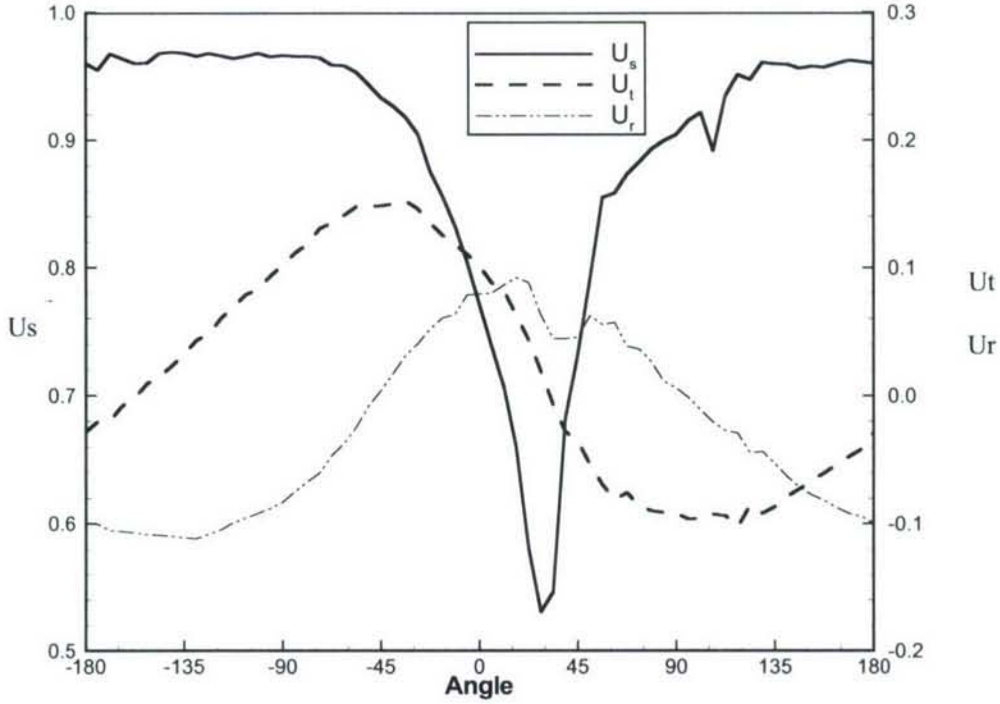

Figure A8. Velocities at starboard shaft, 30 knots, r/R = 1.00.

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